Fatigue Risk Management Systems (FRMS) for Cabin Crew:

Evaluation of the current status and future needs

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ABSTRACT

Fatigue Risk Management Systems (FRMSs) are a more recent approach to improving safety and increasing operational flexibility and have been utilised in the operation of Ultra-long range (ULR) flights that exceed traditional flight and duty time limits. Because ULR scheduling and FRMS processes for cabin crew are predominantly based on flight crew data, little is known about how well these work for cabin crew. A mixed methods approach was used to evaluate the current status of, and future needs for, FRMS for cabin crew.

The sleep of 55 cabin crew was monitored throughout a ULR trip between Johannesburg and New York. On each flight, crewmembers rated their fatigue, sleepiness, and workload, and completed a 5-minute Psychomotor Vigilance Task at key times. In addition, semi-structured focus group discussions were held and thematic analysis was undertaken with data from 25 cabin crew with ULR experience.

Findings demonstrate that collecting fatigue monitoring data, as for flight crew, is also feasible for cabin crew, provided that operational differences between cabin crew and flight crew are considered. Using mitigations that mirror those used for flight crew, cabin crew fatigue can be managed effectively on a ULR flight.

The findings also highlight the importance of: a) considering workload, the cumulative effects of fatigue across the entire ULR trip, and the impact of the entire schedule worked, for improving the management of cabin crew fatigue associated with ULR operations, and; b) sufficient rest for adequate recovery and work-life balance in support of employees' overall health and well-being; c) company support, in the form of fatigue-related processes and resources, effective communication and management's engagement with cabin crew.

Priority should be given to fatigue management training for cabin crew, which may also enhance perceived company support and assist with achieving a better work-life balance. Viewing fatigue as a compound hazard, the management of fatigue-related safety risks and health risks may be optimized if FRMS and OHS can be more closely linked or integrated, in support of improving cabin crews' safety and service, and health and well-being.

PREFACE

This thesis comprises two studies conducted with cabin crew at South African Airways. The first study, a ULR validation study, came about as follows.

South African Airways (SAA) contracted the Sleep/Wake Research Centre in 2010 to design and conduct scientific studies with both flight crew and cabin crew, which would: 1) evaluate the effects of a newly introduced ULR flight operation between Johannesburg and New York (JNB-JFK-JNB) on crewmember sleep, and the potential consequences for crewmember fatigue and performance during the trip, and for post-trip recovery, and 2) provide essential data to inform fatigue risk management activities at SAA. For logistical reasons, the cabin crew study began once the flight crew study had been completed.

Prior to my provisional enrolment, I began working on the cabin crew ULR study as a Junior Research Officer and contributed to the study design, prepared all study materials and was responsible for coordinating the data collection and database development. The data collection began on 27 August 2012.

In February 2013, I enrolled part-time as a doctoral student. During my provisional enrolment, I completed the data collection, all analyses addressing the research questions set out in the contract, and I first-authored a technical report for SAA (completed April 2014).

As part of the contract fulfilment for the cabin crew ULR study, a visit to SAA in Johannesburg, South Africa was arranged for me to present the study findings to management and union representatives. This visit provided a unique opportunity to conduct focus groups with cabin crew at SAA, which formed the second study of this thesis. The focus group study aimed to better understand cabin crews' views on fatigue and strategies for mitigating it, particularly in the context of ULR operations. The participants in the focus group study asked for a technical report on the study findings to be presented to airline management (completed March 2018), which I was the primary author of.

A list of all outputs associated with this thesis is included in Appendix Y.

ACKNOWLEDGEMENTS

This PhD thesis has been quite a journey, made possible only with the tremendous help and support of many individuals along the way.

First and foremost, I would like to thank the cabin crew who took part in this research, for their time and effort, and openness to share their experiences and views on fatigue and the challenges they face managing it. I hope the work presented in this thesis will be of benefit to this important workforce.

Both the ULR validation study and focus group study were made possible by Captain Wynand Serfontein, Fatigue Specialist at South African Airways. I am extremely grateful for his support and the enormous amount of time, energy and effort he put into participant recruitment and data collection for the ULR validation study, with help of research assistants Barbie Moonsamy, Carol Myaluza, Ayanda Toti, Beverly Seabi, Heather Marule, Samantha Narisamulu, Carey Bouwer and Masilo Matseke.

A special thanks to Masilo Matseke, Adhoc Service Trainer, Customer Standards and Training at South African Airways, for his tremendous help with the focus group study, including the recruitment of all research participants, assistance with facilitation of the focus groups and following up on release-of-transcript forms from participants.

At the Sleep/Wake Research Centre, I would like to thank Rosie Gibson, Sophie McCashin and Hannah Timms for their assistance with the data processing, Tracy Anderson for transcribing the audio recordings, and Professor Antonia Lyons at the School of Psychology, for her expert advice and guidance on the qualitative data analysis.

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I thank all my colleagues and friends at the Sleep/Wake Research Centre, both past and present, for making the centre a wonderful place of work. Special thanks to Karyn O'Keeffe, Lora Wu, and PhD buddies (past and present), Rosie Gibson, Bronwyn Sweeney, Jennifer Zaslona, Dee Muller, and Clare Ladyman - without your tremendous support, encouragement, advice, coffees and laughs I would never have made it this far.

To my wonderful family - Steve, Maya, Annie, and Maik, my extended family, and friends on both sides of the globe - I can't thank you enough for your love and support, patience and encouragement.

This dissertation is lovingly dedicated to my mother, Annie Harleman,

who taught me to work hard, always do my best,

and 'niet bij de pakken neer te zitten' (not give up)

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LIST OF ABBREVIATIONS

ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
CAMI	Civil Aerospace Medical Institute (US Federal Aviation Administration)
CRM	Crew Resource Management
EASA	European Aviation Safety Agency
EEG	Electroencephalography
EMG	Electromyogram
EOG	Electro-oculogram
FAA	United States Federal Aviation Administration
FRM	Fatigue Risk Management
FRMS	Fatigue Risk Management System
FSAG	Fatigue Safety Action Group
HPA-axis	Hypothalamic-pituitary-adrenocortical axis
ICAO	International Civil Aviation Organization
JNB	O. R. Tambo International airport, Johannesburg

JFK	John. F. Kennedy International airport, New York City
KSS	Karolinska Sleepiness Scale
NASA	National Aeronautics and Space Administration (USA)
NASA-TLX	NASA Task Load Index
NREM	Non-rapid eye movement sleep
OHS	Occupational Health and Safety
PSG	Polysomnography
PVT	Psychomotor Vigilance Task
Raw TLX	NASA Task Load Index without the weighting assessment
REM	Rapid eye movement sleep
SAA	South African Airways
SCN	Suprachiasmatic Nucleus (master circadian pacemaker)
SD	Standard Deviation
SMS	Safety Management System
SP	Samn-Perelli Crew Status Check
SPIs	Safety Performance Indicators
SWA	Slow wave activity
SWS	Slow wave sleep

TA	Thematic Analysis
TOC	Top of climb; the point at which the aircraft transitions from the climb phase to the cruise phase of flight
TOD	Top of descent; the point at which the aircraft transitions from the cruise phase to the landing phase of flight
TST	Total Sleep Time
ULR	Ultra-long range; planned flight duration in excess of 16 hours
UTC	Universal Time Coordinated
WOCL	Window of Circadian Low

"There is a time for many words, and there is also a time for sleep"

~ Homer

CHAPTER 1 INTRODUCTION & RATIONALE

1.1 The role & responsibilities of cabin crew

The demand for air travel, both domestically and internationally, has doubled since 1995 and continues to grow (International Air Transport Association, 2018). Cabin crew are pivotal to the safety and comfort of passengers in-flight. Cabin crew perform a wide range of service-related duties, including, but not limited to assisting passengers with their carry-on luggage, assisting passengers with young children, serving refreshments and meals, and responding to passenger calls in a timely manner. However, their most important role is to ensure cabin and passenger safety during flight. This includes the safe boarding of passengers, arming and disarming doors, maintaining passenger safety during turbulence, identifying and managing non-regular inflight situations (smoke, fire, loss of cabin pressure, unruly passengers, medical incidents), and in some cases they are required to manage an emergency situation that may result in an evacuation (Butcher, Barnett, Buckland, & Weeks, 2018; Damos, Boyett, & Gibbs, 2013; MacDonald, Deddens, Grajewski, Whelan, & Hurrell, 2003; Moebus, 2008; Nesthus, Schroeder, Connors, Rentmeister-Bryant, & DeRoshia, 2007). The European Transport Safety Council has estimated that 90% of aircraft accidents are survivable, but fast and safe evacuation is of vital importance to the outcome of the event (European Transport Safety Council, 1996). Thus, cabin crew are required to be sufficiently alert and cognitively able to perform safety-related tasks promptly, particularly in non-routine situations (Moebus, 2008).

1.1.1 Is fatigue a problem for cabin crew?

The aviation industry offers 24/7 service, which creates a number of challenges for cabin crew. They often experience fatigue resulting from irregular work schedules that include consecutive early starts, late finishes, night work, time zone changes, and long duty periods, which cause sleep loss, and circadian rhythm disruption (Avers, King, Nesthus, Thomas, & Banks, 2009; Avers et al., 2011; Castro, Carvalhais, & Teles, 2015; Cho, Ennaceur, Cole, & Suh, 2000; Holcomb et al., 2009; Houston, Dawson, & Butler, 2012; Jackson, Bourgeois-Bougrine, Hilditch, & Holmes, 2009; Lowden & Åkerstedt, 1998b, 1999; MacDonald et al., 2003; Nesthus et al., 2007; Ono, Watanabe, Kaneko, Matsumoto, & Miyao, 1991; Sharma & Shrivastava, 2004). Due to economic pressures, airlines routinely schedule cabin crews' duty and rest periods to the regulatory limits (Banks, Avers, Nesthus, & Hauck, 2009), resulting in more extreme work schedules in comparison to those for flight crew (Avers & Johnson, 2011).

In addition, workload has been identified as an important factor contributing to cabin crew fatigue (Bergman & Gillberg, 2015; MacDonald et al., 2003; Nesthus et al., 2007; Samel, Vejvoda, & Maaß, 2002; Smolensky, Lee, Mott, & Colligan, 1982; Vejvoda et al., 2001). They are required to perform a wide range of tasks, including physically demanding ones, which need to be completed within the scheduled flight time, and in accordance with the airline's performance standards (Avers, King, et al., 2009; Damos et al., 2013; Glitsch et al., 2007; Hagihara, Tarumi, & Nobutomo, 2001; MacDonald et al., 2003; Nesthus et al., 2007).

It is therefore not surprising that cabin crew experience work-related fatigue. An analysis of fatigue events reported by cabin crew at a British airline during the course of a year (68 cases per 1000 persons), found that in 93% of cases, cabin crew were stood down, or unable to work because of fatigue (Houston et al., 2012). The rostered duty pattern was identified as the primary cause of fatigue in 27% of reported events, whereas roster disruptions accounted for 24%, domestic issues accounted for 23%, and issues with layover accommodation or transport accounted for 17% of reported fatigue events (Houston et al., 2012).

The Federal Aviation Administration's (FAA) Civil Aerospace Medical Institute (CAMI), in collaboration with the National Aeronautics and Space Administration (NASA), conducted a comprehensive body of work on cabin crew fatigue, that was instigated by the United States Congress following growing concerns that the minimum crew rest regulations may not provide cabin crew with sufficient time for rest in between duty periods (Nesthus et al., 2007). This body of work included a large-scale survey conducted with 9180 cabin crew. In this survey, 52% of respondents reported that they had 'nodded off' while working on a flight. Eighty-four percent of all respondents reported being fatigued while on duty, of which 71% reported that their safety-related performance was affected (Avers, King, et al., 2009).

1.2 Defining fatigue

In the scientific literature, the inconsistent use of the word '*fatigue*' as a synonym for a broad range of symptoms including sleepiness (readiness to fall asleep), or tiredness (diminished alertness, motivation, and/or mood without indicating a specific causal factor), or changes to physical or mental performance, has led to numerous definitions of fatigue which lack completeness and/or usefulness to varying degrees (Balkin & Wesensten, 2011).

In the aviation environment, fatigue has been defined as "*a physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to perform safety-related operational duties*" (International Civil Aviation Organization, 2016).

This definition has the advantage of explaining that fatigue-related impairment has a physiological cause, so that even the most motivated, highly trained and professional individuals are susceptible to it. The definition also highlights that mitigations to better manage fatigue need to address disruption to sleep and the circadian body clock, and workload.

1.3 The basics of sleep

Like food and water, sleep is an essential physiological need. It is required to sustain normal functioning (Banks & Dinges, 2007), a conclusion based in part on a series of experimental animal studies which showed that total sleep deprivation leads to severe debilitation and death (Rechtschaffen & Bergmann, 2002).

Based on comparative studies of sleep in different mammals, and total sleep deprivation and sleep restriction experiments involving humans, sleep is thought to serve multiple functions, including cellular repair and defence, re-organisation of neural connections in the brain (plasticity), learning, memory consolidation and integration, as well as the restoration of waking-induced cognitive performance degradation (Krueger, Frank, Wisor, & Roy, 2016; Mignot, 2008). Chronic short sleep has been associated with impaired immune function (Prather, Janicki-Deverts, Hall, & Cohen, 2015), as well as an increased risk for obesity, diabetes mellitus, hypertension, and cardiovascular disease (Itani, Jike, Watanabe, & Kaneita, 2017).

In simple terms, sleep can be defined as a "*reversible behavioural state of perceptual disengagement from, and unresponsiveness to the environment*" (Carskadon & Dement, 2017). While a single measure of sleep does not exist, it can be identified by evaluating a combination of physiological and behavioural variables that correlate with sleep (Krueger et al., 2016).

With the use of polysomnography (PSG), which involves the recording of cortical activity from the brain (electroencephalography; EEG), eye movements (electro-oculogram), and surface muscle tone (electromyogram), two distinct states of sleep have been identified that alternate cyclically. These are non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep (Carskadon & Dement, 2017). Based on specific features in the EEG, NREM sleep has been further divided into three or historically, four stages (N1, N2, and N3 sleep; or Stage 1, 2, 3, and 4 sleep), which roughly parallel the progression from light sleep to deep, or slow wave sleep (SWS) (Berry et al., 2015; Rechtschaffen & Kales, 1968). Whereas NREM sleep is associated with reduced firing of neurons, REM sleep is characterized by EEG activity closely resembling that seen during wakefulness. Additionally, this sleep stage features episodes of rapid eye movements, and muscle atonia, and is normally associated with vivid dreaming (Carskadon & Dement, 2017).

The distribution of NREM-REM sleep cycles across a sleep period, referred to as sleep structure, or sleep architecture, is represented graphically in Figure 1-1, also known as a '*hypnogram*'. Sleep is normally entered through NREM stage 1 sleep, after which it quickly progresses to NREM stage 2 and subsequently to NREM stage 3, or SWS. As sleep deepens, the brain's threshold for external stimuli, such as noise, increases so that arousal from sleep requires a stronger stimulus. The transition from NREM sleep to REM sleep is usually preceded by an 'ascent' into the lighter stages of NREM sleep accompanied by body movements. Across the night time sleep period, the duration of each NREM-REM cycle varies, but is on average approximate 90-110 minutes. In a healthy young adult, NREM stage 2 accounts for about 50% of a night time sleep period. Slow wave sleep (SWS) accounts for about 20% of the sleep period, and is predominant during the first third of a night time sleep period. REM sleep episodes on the other hand are longest during the last third and account for about 25% of the total sleep period (Carskadon & Dement, 2017).

The hypnogram in Figure 1-1 implies that sleep is continuous. However, arousals form a normal aspect of sleep and can occur spontaneously or in response to an external stimulus, such as noise. Arousals, which may be observed in the PSG recording as abrupt transitions (of at least 3 seconds in duration) to a lighter stage of sleep or wakefulness, or as an increase in blood pressure or heart rate, cause sleep structure to be fragmented. With increased rates of sleep fragmentation, the recuperative value of sleep decreases, leading to greater daytime sleepiness, and impaired performance (Carskadon & Dement, 2017; Stepanski, 2002).

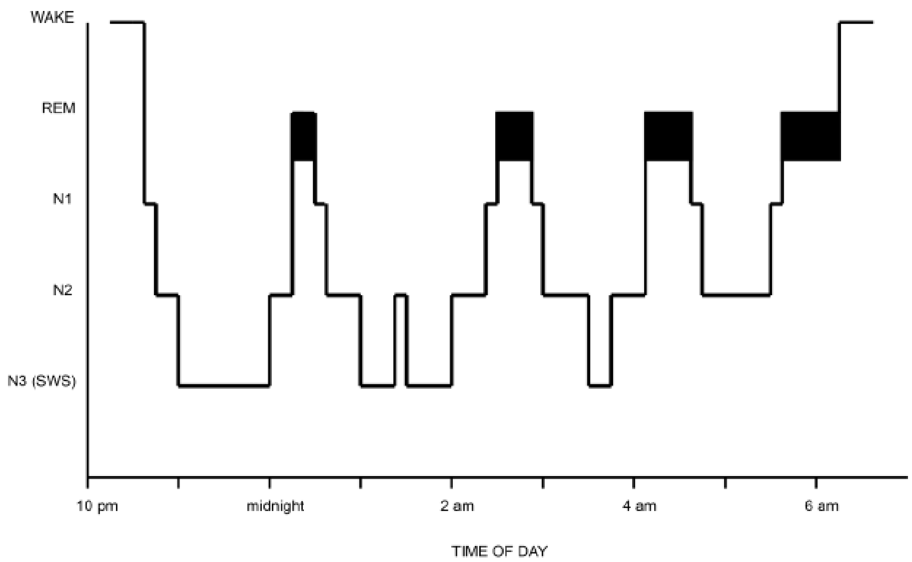

Figure 1-1 Hypnogram of a healthy young adult's normal night time sleep (modified from Gander, 2003)

1.3.1 The sleep-wake cycle

The sleep-wake cycle is regulated primarily by two endogenous processes, namely a circadian process and a homeostatic process (Achermann & Borbély, 2017; Czeisler & Buxton, 2017).

1.3.1.1 Circadian process

The light-dark cycle that results from the earth's rotation around its axis, has shaped the behaviour and physiology of life on earth. Humans evolved as a diurnal species, being active during the light phase, and sleeping predominantly during the dark phase of the earth's 24-hour rotation. This daily rhythm of sleep and wakefulness is not simply a behavioural response to the 24-hour changes in the environment. Instead, it is regulated by an autonomous, internal time-keeping system that drives the daily rhythms that exist in the body's biochemical, physiological, and behavioural processes to ensure these are optimally timed with each other and with the external environment. It enables the organism to anticipate, and adapt to the daily changes in its environment (Buijs et al., 2016; Deboer, 2018; Roenneberg & Merrow, 2016). In the absence of periodic changes in the external environment, these internal, or endogenous rhythms continue to oscillate close to, but not exactly in 24-hour periods (Czeisler et al., 1999) and are therefore referred to as circadian rhythms, from the Latin '*circa diem*', which means '*about a day*' (Turek & Zee, 1999).

In mammals, the circadian system is organized hierarchically, involving a master circadian pacemaker (circadian biological clock), and peripheral clocks that are found in most cells, tissues and organs (Buijs et al., 2016; Roenneberg & Merrow, 2016; Vetter, 2018). The master circadian pacemaker has been identified as the suprachiasmatic nucleus (SCN) in the hypothalamus of the brain, above the optic chiasm where the optic nerves cross (Czeisler & Buxton, 2017).

The SCN has a period (tau) that, on average, is slightly longer than 24 hours (an estimated 24.2 hours, in healthy young and older individuals) (Czeisler et al., 1999). However, through a process of active synchronisation, or entrainment, the SCN's internal rhythm is able to stay in step with the external 24-hour light-dark cycle (Czeisler & Buxton, 2017; Roenneberg & Merrow, 2016; Vetter, 2018). The process of entrainment requires the input of rhythmic '*zeitgebers*' (German for 'time givers'). The light-dark cycle is the primary zeitgeber influencing the SCN, whereas other zeitgebers, including the sleep-wake cycle, physical activity, and meal timing exert their influence to a lesser degree (Czeisler & Buxton, 2017; Wehrens et al., 2017). Non-image forming, light-sensitive cells in the retina relay photic information directly to the SCN via the retino-hypothalamic tract, which enables the SCN to synchronize its activity to the 24-hour day. Through various outputs, the SCN relays its 24-hour rhythm to other processes, including behavioural (activity, food intake), autonomic (e.g. temperature), and hormonal (e.g. melatonin, cortisol) rhythms, as well as to the peripheral clocks (Buijs et al., 2016; Roenneberg & Merrow, 2016; Vetter, 2018). In turn, signals from the peripheral clocks are sent to the SCN, either directly or indirectly, allowing the SCN to 'fine tune' its rhythmic output, making it more robust to sporadic environmental variations (Buijs et al., 2016; Grosbellet & Challet, 2017).

However, acute challenges such as shift work and transmeridian travel (see Section 1.6) change the timing of zeitgebers, particularly light exposure. Late evening or night exposure to light shifts the timing of circadian rhythms later (phase delay), whereas early morning exposure to light shifts the timing of circadian rhythms earlier (phase advance) (Czeisler & Buxton, 2017). This disrupts the phase relationship between the external light-dark cycle and the endogenous circadian rhythms, and between one or more endogenous rhythms (Buijs et al., 2016; Qian & Scheer, 2016; Vetter, 2018).

While it is not possible to measure the SCN's activity directly, an individual's biological clock time, or circadian phase, can be inferred from the phase relationship between the light-dark cycle and the endogenous rhythms in biological markers that are tightly controlled by the SCN, such as core body temperature, melatonin, and cortisol (Czeisler & Buxton, 2017).

One of the daily rhythms regulated by the SCN is sleep propensity, or sleepiness, which influences the timing for sleep. However, in humans, external factors, such as work, family, and social commitments also drive the timing of sleep (Beersma & Gordijn, 2007).

In a healthy individual synchronized with the 24-hour light-dark cycle, the rhythm in sleep propensity is inversely related to the rhythm in core body temperature, as illustrated in Figure 1-2. Coinciding with the peak in core body temperature rhythm is the '*evening wake maintenance zone*', which is a period during the early evening when the drive for wakefulness is high, and sleep is difficult to initiate or maintain (Dijk & Czeisler, 1995; Strogatz, Kronauer, & Czeisler, 1987). The period between 2am-6am, sometimes referred to as the '*Window of Circadian Low*' (WOCL), is when sleepiness is highest (Dinges, Graeber, Rosekind, Samel, & Wegmann, 1996). As the drive for wakefulness increases during the morning hours, it signals an 'internal alarm clock' after which staying asleep becomes difficult (Åkerstedt, Kecklund, & Knutsson, 1991; Strogatz, 1987).

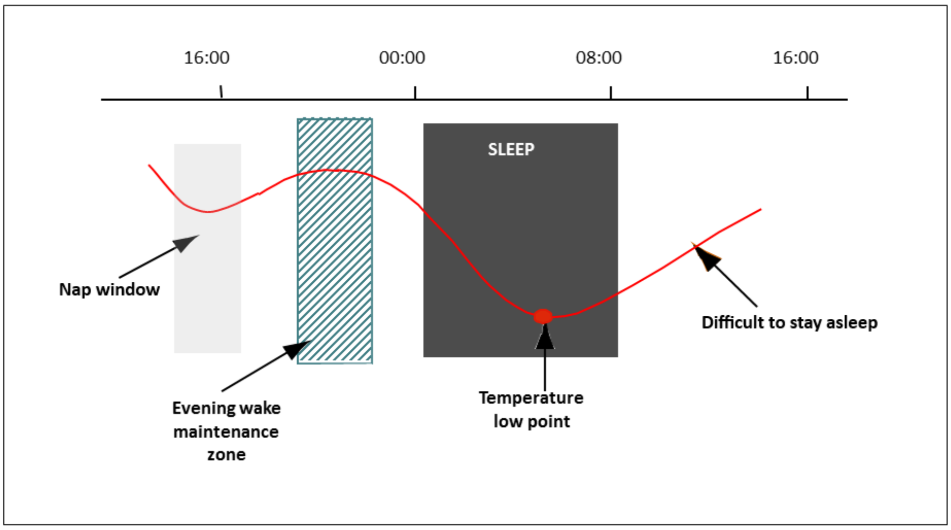

Figure 1-2 Diagram of circadian influence on sleep (Gander, 2003)

As well as sleep propensity, the circadian body clock also regulates the daily rhythm in alertness and cognitive performance and their rhythmicity follows a pattern similar to that seen in core body temperature (Gabehart & Van Dongen, 2017).

Inter-individual differences exist in the phase of entrainment between the SCN and the day-night cycle. This is known as *chronotype*, which is most apparent in the preferred timing of sleep and wake between extreme morning-types and extreme evening-types (Roenneberg, Wirz-Justice, & Merrow, 2003).

1.3.1.2 Homeostatic process

The observation that extended sleep, or recovery sleep, occurs following sleep loss, is indicative of a homeostatic process that also regulates sleep (Deboer, 2018; Porkka-Heiskanen, 2013). Slow-wave activity (SWA) in the EEG has been shown to have a dose-response relationship with prior sleep and prior wakefulness, and thus serves as a physiological marker of sleep pressure (Borbély, Daan, Wirz-Justice, & Deboer, 2016). As the pressure for sleep increases, an individual's ability to remain awake eventually dwindles, as demonstrated by the occurrence of brief intrusions of sleep known as micro-sleeps, and 'dozing off' involuntary (Bougard et al., 2018; Goel, Rao, Durmer, & Dinges, 2009; Torsvall & Åkerstedt, 1988).

Observed inter-individual differences in the rate of SWA accumulation and dissipation indicates that there are stable trait-like differences in the homeostatic process which contribute to differences in resilience to sleep loss (Rusterholz, Tarokh, Van Dongen, & Achermann, 2017).

1.3.1.3 Two-process model of sleep-wake regulation

The two-process model of sleep-wake regulation, first proposed by Borbély (Borbély, 1982), describes how the circadian process (Process C) and homeostatic process (Process

S) are assumed to interact to produce consolidated periods of sleep and wake. This model has been validated and used extensively to predict the timing and duration of sleep, and forms the core of models predicting waking alertness and performance (Achermann & Borbély, 2017; Åkerstedt & Folkard, 1997; Borbély, 1982; Borbély et al., 2016; Ingre et al., 2014).

As illustrated in Figure 1-3, this model implies that in an entrained individual, sleep pressure (Process S; solid black line) increases exponentially across the waking period (denoted as 'W' on the horizontal axis). The circadian process (Process C; dotted lines) sets boundaries to Process S, initiating sleep when Process S reaches the upper threshold of Process C, thus preventing sleep pressure from continually increasing. During the sleep period (denoted as 'S' on the horizontal axis), sleep pressure dissipates exponentially and when Process S reaches the lower threshold of Process C, sustained wakefulness occurs (Beersma & Gordijn, 2007; Borbély et al., 2016).

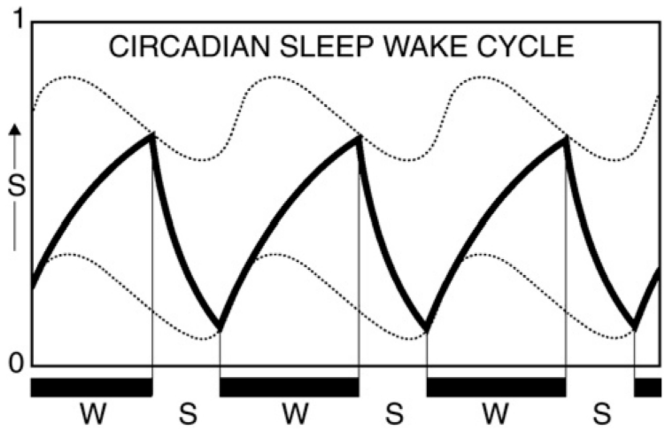

Figure 1-3 The Two-Process Model of Sleep Regulation (Beersma & Gordijn, 2007)

The duration and quality of sleep are largely determined by the timing of sleep. The homeostatic drive for sleep is greatest at sleep onset, facilitating sleep in the first part of the night during which SWS predominates. As sleep pressure decreases through the production of SWS, the circadian drive for sleepiness increases. This results in consolidated sleep across the night (Beersma & Gordijn, 2007; Borbély et al., 2016; Dijk & Czeisler, 1994).

Limitations of the two-process model include its inability to accurately predict the cumulative effects of chronic sleep restriction, or account for inter-individual differences in resilience to sleep loss (Achermann, 2004; Rusterholz et al., 2017). Furthermore, while the model assumes that Process S and Process C are two independent processes, evidence from sleep deprivation studies indicates that increased homeostatic sleep pressure attenuates the circadian influence on sleep (Deboer, 2018).

1.3.2 Sleep inertia

The reduced alertness, feeling of grogginess, disorientation, and impaired performance that may be experienced immediately upon waking is known as sleep inertia (Ferrara & De Gennaro, 2000). Considered as a third process in the three-process model (Folkard, Akerstedt, Macdonald, Tucker, & Spencer, 1999) - an extension of the two-process model -, the effects of sleep inertia typically dissipate within an hour after waking (Achermann, Werth, Dijk, & Borbely, 1995; Hilditch, Centofanti, Dorrian, & Banks, 2016; Signal, van den Berg, Mulrine, & Gander, 2012; Wertz, Ronda, Czeisler, & Wright, 2006). However, prior sleep loss, extended wakefulness prior to the sleep period, and/or sleep depth can exacerbate the effects of sleep inertia (Balkin & Badia, 1988; Ferrara & De Gennaro, 2000). Evidence from a brain imaging study suggests that sleep inertia occurs due to the varying rates in reactivation of the different brain regions, as well as the reorganisation of the functional connectivity among these brain regions to achieve full wakefulness (Balkin et al., 2002).

1.3.3 Factors influencing sleep quality

1.3.3.1 Ageing

Ageing is associated with less consolidated night time sleep and reduced sleep quality, due to a reduction in SWS, more nighttime awakenings, and an advance in sleep timing relative to the day-night cycle as well as to body clock time (Duffy, Zitting, & Chinoy, 2015). Fatigue monitoring studies involving flight crew indicate that older crewmembers have shorter, more disrupted in-flight sleep compared to their younger colleagues (Signal, Gander, van den Berg, & Graeber, 2013; Signal, van den Berg, Travier, & Gander, 2004).

1.3.3.2 Environmental factors

A range of environmental factors can influence the quality of sleep, including noise, artificial light, and ambient temperature (Carskadon & Dement, 2017; Czeisler & Buxton, 2017; Irish, Kline, Gunn, Buysse, & Hall, 2015). Noise, as a prevalent cause of sleep disruption, has been shown to increase the number of cortical (EEG) and cardiac arousals, although this is moderated by the characteristics of the noise (type, relevance), and the individual's sensitivity to noise during sleep (Basner, Müller, & Elmenhorst, 2011; McGuire, Müller, Elmenhorst, & Basner, 2016; Zaharna & Guilleminault, 2010).

Survey data from cabin crew indicate that random noise and ambient temperature are key factors disturbing their sleep, more so when sleeping away from home (Avers, King, et al., 2009). Based on self-reports from flight crew, these factors, as well as low humidity, also affect crewmembers' ability to obtain good quality sleep in flight (Pascoe, Johnson, Montgomery, Roberston, & Spencer, 1994; Zaslona, O'Keeffe, Signal, & Gander, 2018). However, findings from studies objectively assessing the effect of these factors on crewmembers' in-flight sleep have been inconclusive (Pascoe, Johnson, Roberston, &

Spencer, 1995; Robertson, Spencer, Stone, & Johnson, 1997; Simons, Valk, de Ree, Veldhuizen van Zanten, & d'Huyvetter, 1994).

The type of in-flight crew rest facility greatly influences crewmembers' sleep quality, which, based on polysomnographic recordings, is significantly better in a lie-flat bunk than in a reclining seat (Nicholson & Stone, 1987; Spencer & Roberston, 2000), and significantly better in a reclining seat with back angle to the vertical of at least 40 degrees (similar to a business-class seat), than in a seat with limited recline (similar to an economy-class seat) (Nicholson & Stone, 1987; Roach, Matthews, Naweed, Kontou, & Sargent, 2018). However, influence of psychological factors on sleep, such as privacy/personal space, has not been well studied (Flynn-Evans, Caddick, Gregory, & Center, 2016).

1.3.3.3 Stress

Based on self-reports from cabin crew, stress is a salient factor disturbing their sleep (Avers, King, et al., 2009). Stress is an adaptive physiological 'fight-or-flight' response in order to cope with an external stressor. Activation of the hypothalamic-pituitary-adrenocortical (HPA) axis in response to the stressor leads to an increase in cortisol and adrenaline for mobilizing energy and increasing cardiac output, while slowing down other processes such as digestion and immune responses (van Reeth et al., 2000). Stress has been associated with fragmented sleep, less total sleep and less slow-wave sleep (Kim & Dimsdale, 2007) and evidence suggests a bi-directional relationship between stress and sleep, with the threshold for perceived stress being lower following sleep loss (Minkel et al., 2012).

1.4 Sleep loss

Following recent systematic reviews of epidemiological and laboratory-based studies, consensus has been reached that adults require 7-9 hours of sleep per day for maintaining optimal functioning and health (Hirshkowitz et al., 2015; Watson et al., 2015).

In previous field studies with cabin crew, similar durations have been reported for sleep at home on free days, with averages ranging from 7.1 hours to 8.4 hours. However, on days with flying duties, sleep durations were typically much shorter (Buck, Tobler, & Borbely, 1989; Härmä, Suvanto, & Partinen, 1994; Lowden & Åkerstedt, 1998b, 1999; Vejvoda et al., 2000). More recently, a field study which monitored the sleep of 202 cabin crew during a 3-4 week period showed that they obtained an average of 6.3 hours sleep on free days, 5.7 hours of sleep on work days, and even less when operating international flights (mean = 4.9 hours) (Roma, Mallis, Hursch, Mead, & Nesthus, 2010).

Early duty start times have been shown to curtail cabin crews' sleep, due to a lack of sufficiently advancing bedtime to compensate for the early rise time, and believed to result from difficulties initiating sleep during the evening wake maintenance zone, and/or prioritizing social activities during the early evening (Kecklund, Åkerstedt, & Lowden, 1997). While late evening finishes are typically not associated with shorter sleep (Drake, Roehrs, Richardson, Walsh, & Roth, 2004; Pilcher, Lambert, & Huffcutt, 2000), family obligations requiring an earlier rise time may still lead to sleep curtailment (Drake & Wright, 2017).

Failing to obtain an adequate amount of physiologically normal sleep leads to a ' sleep debt' (Banks, Dorrian, Basner, & Dinges, 2017). Restricting a single nighttime sleep opportunity by as little as two hours has been shown to produce measurable increases in sleep propensity (Rosenthal, Roehrs, Rosen, & Roth, 1993).

Although individuals differ in their susceptibility to sleep loss (Rupp, Wesensten, & Balkin, 2012; Van Dongen, Baynard, Maislin, & Dinges, 2004), the effects of sleep restriction across successive days are cumulative and dose-dependent (Belenky et al., 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003). Under conditions of moderate sleep restriction (7 hours or 5 hours in bed each night), similar to that observed for cabin crew in Roma et al's (2010) study, cognitive performance impairment tended to stabilize after 5 days of sleep restriction, albeit at a reduced level (Belenky et al., 2003). Subjective sleepiness appeared to stabilize much faster than cognitive performance (Belenky et al., 2003). The differential impact of chronic sleep restriction on cognitive performance and subjective sleepiness suggests that individuals may underestimate the extent to which their performance is affected when sleep is chronically restricted, if they solely rely on their self-perceived alertness levels to assess their performance capacity (Zhou et al., 2012).

The effects of chronic sleep restriction have been shown to interact with circadian phase, resulting in more pronounced cognitive performance decrements during the biological night in comparison to not being sleep-restricted, even when preceded by a short duration of wakefulness (Zhou et al., 2011). These findings have important implications for cabin crew who are scheduled to work during nighttime hours following successive days of restricted sleep.

1.4.1 Recovery from sleep loss

Following sleep loss, dissipation of the increased sleep pressure occurs by prolonging the time course of SWS during sleep, and by intensifying SWS, leading to longer, and deeper sleep, and therefore sleep loss does not require hour-for-hour recovery (Bonnet, 2011). However, at least two consecutive (biological) nights of unrestricted sleep are required for the structure of sleep to return to normal, with more SWS occurring during the first night (at the expense of REM sleep), and recovery of REM sleep during the second night (Bonnet, 2011).

Recovery of neurocognitive performance following a single night of acute sleep deprivation has also been shown to require two nights of sleep, provided that sufficient time is allowed (9 hours in bed) and no residual sleep debt existed beforehand (Lamond et al., 2007). However, subjectively, individuals no longer felt impaired following one 9-hour sleep opportunity (Lamond et al., 2007).

However, the recovery process following chronic sleep restriction takes longer than that, which is believed to be a consequence of the adaptive changes in the brain that occurred in response to chronic sleep restriction (Belenky et al., 2003). Factors influencing the rate of recovery include the degree of sleep restriction experienced, the number of recovery days provided, the time available for sleep each night, as well as the individual's resilience to sleep loss (Banks, Van Dongen, Maislin, & Dinges, 2010; Belenky et al., 2003; Bougard et al., 2018; Dinges et al., 1997; Rupp et al., 2012; Rupp, Wesensten, Bliese, & Balkin, 2009; Van Dongen et al., 2004). Recovery sleep in these studies occurred during the biological night and in sleep-conducive environments that were quiet, dark, and without distractions or competing activities, suggesting that for cabin crew, recovery may take longer if their sleep occurs in a less favourable environment, or at adverse circadian times.

Extending sleep prior to acute sleep loss or prior a period of sleep restriction has been shown to slow cognitive impairment during, and improve performance more quickly afterwards, even though subjective sleepiness did not differ from the habitual sleep condition (Arnal et al., 2015; Rupp et al., 2009). Whether the benefits are due to the mere elimination of residual sleep pressure, or the cause of any underlying changes in the homeostatic process is presently not known (Axelsson & Vyazovskiy, 2015).

1.4.1.1 Split sleep

As a consequence of working irregular hours, a consolidated sleep period may not be feasible, and instead sleep across the 24-hour period may be split into two or more sleep periods, comprised either of a main sleep plus nap sleep, a main sleep plus multiple naps, or multiple naps without a main sleep (Jackson, Banks, & Belenky, 2014). Previous laboratory-based studies assessing the recuperative value of a split sleep schedule suggest it does not adversely affect subjective sleepiness or cognitive performance, in comparison to a consolidated nighttime sleep schedule (Jackson et al., 2014; Mollicone, Van Dongen, Rogers, & Dinges, 2008). However, more recently it was found that after controlling for circadian phase, subjective sleepiness following consolidated sleep periods (9.33 hours in bed, alternating with 18.67-hour wake period) was lower than after waking from split sleep (4.67 hours in bed, alternating with 9.33-hour wake periods), even though the total amount of sleep did on average not differ between conditions (Zhou et al., 2015). Yet sleepiness increased as a function of time awake so that in the split sleep schedule, the level of sleepiness was 'reset' more quickly (Zhou et al., 2015). Cognitive performance was also better during the first few hours after waking from consolidated sleep compared to split sleep and declined with increasing duration of time awake (Kosmadopoulos et al., 2014).

In operational settings, the timing and duration of split sleep opportunities are largely dependent on the work schedule, which, for cabin crew, can be highly variable. In the large-scale survey with more than 9000 US-based cabin crew, 69% reported taking naps when at home, while 52% reported taking naps when away from home (Avers, King, et al., 2009). A number of field studies that have monitored the sleep of cabin crew before, during, and after long-haul trips showed that up to 20% of crewmembers would take a pre-flight nap on the day of the outbound flight, and that most would nap during their scheduled in-flight rest break (Lowden & Åkerstedt, 1998a, 1998b, 1999; Vejvoda et al., 2000). Following eastward outbound flights, crewmembers tended to adopt a split sleep schedule during the layover, but not after westward outbound flights (Lowden & Åkerstedt, 1998b, 1999). Napping was also observed on the day of arrival home, and on subsequent post-trip days (Lowden & Åkerstedt, 1998a, 1998b, 1999; Vejvoda et al., 2000).

Studies evaluating the efficacy of napping, whether compensatory or prophylactic, have shown that overall, it is beneficial for reducing the effects of fatigue (Driskell & Mullen, 2005; Ficca, Axelsson, Mollicone, Muto, & Vitiello, 2010).

1.5 Extended wakefulness

Extended wakefulness beyond the typical 16 hours to 18 hours increases sleep pressure and subjective sleepiness, and leads to progressively variable, and greater impairment in cognitive performance (Banks et al., 2017; Doran, Van Dongen, & Dinges, 2001; Van Dongen et al., 2003).

To quantify the relative risk of impaired performance caused by staying awake for an extended period, a number of studies have compared its effects to the effects of alcohol on performance (Dawson & Reid, 1997; Lamond & Dawson, 1999; Williamson & Feyer, 2000). For example, one study showed that after an 8am wakeup, 17 hours of sustained wakefulness, corresponding to 3am, decreased performance on an unpredictable tracking task (measuring hand-eye coordination) to a level equivalent to the impairment seen with a blood alcohol concentration (BAC) of 0.05% (Dawson & Reid, 1997). This is the legal limit for driving in many countries, including New Zealand, Australia, South Africa, and most of Europe (World Health Organization, 2019).

The effects of extended wakefulness, circadian phase, and the cumulative effects of sleep restriction interact. Matthews and colleagues showed that with a longer period of wakefulness, the circadian influence on driving simulator performance increased, and that this effect was even more pronounced after cumulative sleep restriction (Matthews et al., 2012).

Cabin crews' work schedules often include long duty periods. In the United States for example, duty time regulations allow cabin crew to work up to 20 hours[1], provided at least 3 cabin crew members are added to the minimum crew complement and flights either take off or land outside the contiguous United States (Code of Federal Regulations, 2018a, 2018b). Cabin crew operating under the recently revised European flight and duty regulations are allowed to work up to 14 hours without requiring scheduled in-flight rest during their duty period (European Aviation Safety Agency, 2014). In South Africa where the present research with cabin crew took place, the permissible maximum duty period can be extended from 12 hours to 16 hours, if it includes a scheduled in-flight rest taken in a seat (South African Civil Aviation Authority, 2011).

Cabin crews' wakefulness on long duty days is further extended by the time needed for commuting, meals, and personal time required in preparation for sleep, and work (Nesthus et al., 2007).

1.6 Circadian disruption

The irregular work schedules of cabin crew are considered shift work, which in broad terms, refers to any non-standard work pattern that overlaps with a person's normal sleep time (Gander, 2003). Shift work disrupts the sleep/wake cycle by displacing the sleep period to a part in the circadian cycle when sleep is more difficult to initiate or maintain. As well as causing sleep loss, shift work also leads to circadian disruption, as the presence of external

[1] The FAA regulations do not specify any rest requirements during this FDP duration

zeitgebers, such as light and family/social activities, do not allow for complete adaptation to the imposed sleep/wake schedule (Czeisler & Buxton, 2017).

Rapid travel across multiple time zones creates a mismatch between the environmental time and the individual's internal circadian timing, resulting in circadian disruption between the SCN and external time, as well as internally between the SCN and peripheral clocks (Arendt, 2018; Drake & Wright, 2017). The range of overt symptoms associated with this type of circadian disruption are collectively referred to as *jet lag,* and include disturbed sleep, sleepiness, fatigue, gastrointestinal disturbance, and impaired performance (Arendt, 2018; Atkinson, Batterham, Dowdall, Thompson, & van Drongelen, 2014). Circadian adaptation to the local time is facilitated by external zeitgebers (light, meal times, social activities), although the rate is influenced by their strength and timing, as well as the number of time zones crossed, prior flight direction, and by individual differences in tolerance to jet lag (Atkinson et al., 2014; Czeisler & Buxton, 2017; Drake & Wright, 2017; Gander, Gregory, et al., 1998; Gander, Myhre, Graeber, Andersen, & Lauber, 1985; Lowden & Åkerstedt, 1998b, 1999; Suvanto, Partinen, Harma, & Ilmarinen, 1990; Vejvoda et al., 2000). Due to the circadian pacemaker's slightly longer than 24-hour endogenous circadian rhythm (on average), circadian adaptation following a westward transmeridian flight (which effectively lengthens the day) tends to be faster than after an eastward transmeridian flight, which shortens the day (Gander, Gregory, et al., 1998; Suvanto et al., 1990).

Jet lag has been identified as a key factor disturbing cabin crews' sleep on layover, and post-trip at home (Avers, King, et al., 2009; Buck et al., 1989; Härmä, Suvanto, et al., 1994; Lowden & Åkerstedt, 1998b, 1999; Vejvoda et al., 2000). Although layover durations are usually too short for cabin crew to fully adapt to the new time zone, the amount of adaptation that occurs depends in part on the timing of sleep relative to the crewmember's circadian time and local time. For example, in comparison to sleeping on local layover time, retaining a home-based sleep pattern during a two-day layover (after a westward outbound flight crossing 9 time zones) was shown to reduce cabin crews' sleepiness during the layover (Lowden & Åkerstedt, 1998a). However, post-trip recovery did not significantly differ between these sleep strategies and the authors acknowledged that even though crew tried to stay on home time, some circadian adaptation was unavoidable (Lowden & Åkerstedt, 1998a).

Post-trip, cabin crews' recovery from jet lag (based on observed phase shifts in core body temperature, melatonin, and/or cortisol rhythms) following long-haul trips with 2-4 day layovers, and crossing 9-10 time zones, has been shown to take 4 days on average, but this varies between individuals, as well as between the various endogenous circadian rhythms within the individual (Härmä, Laitinen, Partinen, & Suvanto, 1994; Lowden & Åkerstedt, 1998a, 1999; Suvanto, Härmä, Ilmarinen, & Partinen, 1993). Furthermore, jet lag symptoms may be exacerbated if long-haul trips are scheduled in close succession (Samel, Wegmann, & Vejvoda, 1995).

Age-related changes in sleep timing, and difficulties in obtaining consolidated sleep (see Section 1.3.3.1) are also thought to reduce an individual's tolerance to circadian disruption (Duffy et al., 2015).

1.7 Workload

Workload is a multi-dimensional concept resulting from an interaction between task-related aspects (task difficulty, complexity, and intensity), person-related aspects (experience, skill level, internal state such as fitness, and traits such as cognitive processing capabilities), as well as temporal aspects (time on task; time pressure) (Casner & Gore, 2010; Gaillard, 2001; Hart & Staveland, 1988; Lysaght, Hill, Dick, Plamondon, & Linton, 1989).

As illustrated in Figure 1-4, the relationship between workload and fatigue-related performance impairment is an inverted U-shape (Gaillard, 2001; Lysaght et al., 1989). Whereas high workload leads to fatigue as a result of effort expenditure, low workload may unmask the effects of any fatigue present due to the lack of stimulation (Gaillard, 2001).

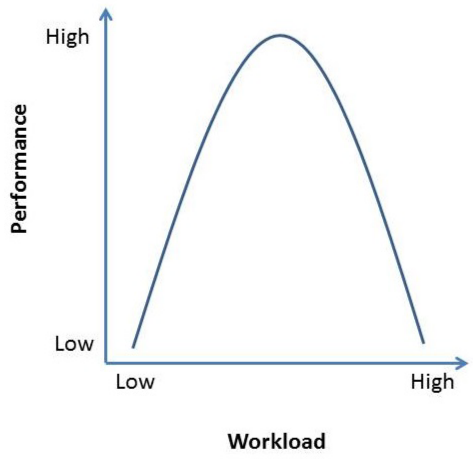

Figure 1-4 The relationship between workload and performance impairment (Figure adapted from Lysaght et al, 1989)

Although the effect of workload on fatigue, and any interactive effects with time-of-day or prior sleep history are not well-documented (McDonald, Patel, & Belenky, 2011), some evidence suggests that fatigue-related performance decrements increase more rapidly when workload is perceived as high. For example, ratings of fatigue made by air traffic controllers increased more rapidly with increasing hours of wakefulness when workload was perceived as high, in comparison to low or medium workload. In addition, a more pronounced time-of-day effect was observed in subjective fatigue ratings when workload was rated as either high or low than when it was rated as moderate (Spencer, Rogers, Birch, & Belyavin, 2000; Spencer, Rogers, & Stone, 1997).

In a more recent study, shift workers at a metallurgic smelter who perceived their workload as high did worse on a psychomotor vigilance task midway through their 12-hour shift when compared to those who perceived their workload as low, more so during night shifts than day shifts (Baulk et al., 2007).

In addition to influencing fatigue-related performance decrements, high workload can also affect subsequent sleep. High cognitive workload has been shown to delay sleep onset, possibly due to sustained activation of the central and/or autonomic nervous systems (Goel, Abe, Braun, & Dinges, 2014). High physical workload and high work demands have been shown to predict disturbed sleep, with the latter possibly having an indirect effect on sleep through the need to 'unwind' after a work period (Åkerstedt, Fredlund, Gillberg, & Jansson, 2002).

The workload of cabin crew has been identified as an important factor contributing to their fatigue (Avers, King, et al., 2009; Bergman & Gillberg, 2015; MacDonald et al., 2003; Samel et al., 2002; Smolensky et al., 1982; Vejvoda et al., 2001). In comparison to flight crew, the work of cabin crew is more physically demanding, involving a lot of walking, lifting of carry-on luggage, and pushing and pulling heavy service trolleys (Avers, King, et al., 2009; Glitsch et al., 2007; Hagihara et al., 2001; Smolensky et al., 1982). To ensure tasks are completed within the scheduled flight time and in accordance with the airline's performance standards, they are often performed under time pressure (Damos et al., 2013; MacDonald et al., 2003; Nesthus et al., 2007).

Compared to long-haul flights, short-haul flights are more likely associated with time-on-task fatigue when there is limited, or no time available for rest in-flight, or between flight sectors (Avers et al., 2011). In laboratory-based studies, effects of time-on-task fatigue, observed as a deterioration in performance with increasing task duration, were exacerbated by sleep loss (Dorrian, Rogers, & Dinges, 2005).

The physical activity associated with cabin crews' tasks is also expected to exacerbate any fatiguing effects of mild hypoxia resulting from working in a pressurized cabin equivalent to 6000-8000 feet above sea level, particularly on longer flights (Aerospace Medical Association, Aviation Safety Committee, & Subcommittee, 2008; Muhm et al., 2007; Smith, 2007).

Factors such as turbulence, the malfunctioning of equipment, and medical incidents can add significantly to their workload (Avers, King, et al., 2009; Damos et al., 2013). Furthermore, because their work requires a high level of social engagement with passengers, it can also be emotionally demanding and stressful (MacDonald et al., 2003; Nesthus et al., 2007; Williams, 2003).

While the workload of cabin crew has been assessed in a number of studies (Hagihara et al., 2001; Samel et al., 2002; Vejvoda et al., 2000), no studies have directly evaluated its association with cabin crews' fatigue.

1.8 Fatigue-related performance impairment

Sleep loss affects many aspects of performance (Goel et al., 2009). Cognitive capacity is believed to function in a hierarchical manner, with complex higher-order functions, such as decision-making, building upon more elementary cognitive processes such as working memory, reaction time, and attention (Killgore & Weber, 2014).

With increasing time awake, psychomotor vigilance performance becomes increasingly variable, which is believed to be a consequence of 'wake-state-instability' that allows the intermittent brief intrusion of sleep into wakefulness (Doran et al., 2001; Goel et al., 2009). As the ability to sustain attention becomes increasingly variable, the speed of responding to a stimulus slows overall, and behavioural lapses (failing to respond to a stimulus in a timely manner) become more frequent and longer (Goel et al., 2009).

As previously described in Section 1.4, the effects of chronic sleep restriction on performance are cumulative and dose-dependent (Belenky et al., 2003), and interact with circadian phase so that the effects are worse during the biological night, irrespective of the duration of prior wakefulness (Zhou et al., 2011).

Few studies have investigated the effect of fatigue on cabin crews' performance. One study which assessed psychomotor vigilance performance of 202 cabin crew across a 3-4 week period found that their performance was, on average, significantly slower at the start of duty days when compared to their optimal performance level (the fastest 10% of responses averaged across all tests taken during the 3-4 week period), more so for cabin crew working in domestic flight operations than those operating international flights (Roma et al., 2010). Although sleep history, time-of-day, and duty duration were not accounted for, cabin crew operating international flights had more lapses in attention at the end of duty compared to those flying domestically (Roma et al., 2010).

Sleep loss has been shown to impair communication by reducing word retrieval and verbal spontaneity, so that a sleep-deprived individual may be less willing to volunteer factual details (Harrison & Horne, 2000).

Decision-making is a particularly complex cognitive process, and at a minimum requires a person to pay attention, process relevant sources of information and anticipate the range of consequences that weigh into the decision (Killgore & Weber, 2014). Sleep loss can impair any combination of these processing stages, making it difficult to study its effect on decision-making (Killgore & Weber, 2014). Findings from functional brain imaging studies indicate that regions involved in higher-order complex cognitive performance, including the prefrontal cortex, are most affected by sleep deprivation (Drummond et al., 2000; Drummond et al., 1999; Harrison & Horne, 2000; Thomas et al., 2000).

Both efficient and effective communication and decision-making are a necessary part of optimal safety performance for cabin crew (International Air Transport Association, 2017). They are core components of Cabin Crew Resource Management (CRM) which involves the optimal coordination of crewmembers, and use of procedures, and equipment (International Air Transport Association, 2017).

1.8.1 Individual versus team performance

The relationship between team work and an individual's fatigue is still poorly understood (Gander et al., 2017). However, two laboratory studies have shown that under fatigued conditions, teams (of four) were more efficient in solving new problems when compared to individuals, possibly due to fatigued team members being able to rely on their less impaired members (Baranski et al., 2007; Frings, 2011).

1.9 Managing fatigue

1.9.1 Prescriptive limits on work time

In commercial aviation, crew fatigue has traditionally been managed through prescriptive duty and flight time limits, which set the daily maximum amount of time on duty, cumulative time on duty and minimum rest periods within and between duty periods (Gander, Hartley, et al., 2011). Thus, these largely consider only time-on-task fatigue. While adequate for some type of operations, this 'one-size-fits-all', single-layer defensive strategy does not take into account all known causes of fatigue that can lead to impaired performance (Cabon, Bourgeois-Bougrine, Mollard, Coblentz, & Speyer, 2002; Cabon et al., 2008; Gander, Graeber, & Belenky, 2011).

The International Civil Aviation Organization (ICAO), which is the United Nations agency responsible for regulating the global aviation industry, requires that its member states have a regulatory framework in place that stipulates how airlines must approach the management of crew fatigue (International Civil Aviation Organization, 2013). Prescriptive rules on duty and rest times continue to be the main regulatory mechanism for managing crew fatigue (Gander, Hartley, et al., 2011). In addition, ICAO also requires that fatigue as a hazard is managed through the airline's safety management system (SMS) processes, implemented for managing safety hazards in general (International Civil Aviation Organization, 2016). To ensure that fatigue as a hazard is managed at an acceptable level of safety requires that the causes and consequences are understood and taken into account (International Civil Aviation Organization, 2013).

Unlike other workplace hazards, fatigue is affected by work-related factors as well as factors outside work. The responsibility for managing fatigue must therefore be shared between the employer and employee. Thus, the airline is responsible for arranging work and rest schedules that provide adequate opportunity for rest, ensuring appropriate staffing levels, and fatigue management training. In turn, it is the crewmember's responsibility to arrive at work fit for duty, and to report any fatigue hazards at work (International Civil Aviation Organization, 2016).

In 2008, before ICAO published its updated guidelines on fatigue management approaches (International Civil Aviation Organization, 2016), the United States Federal Aviation Administration (FAA) conducted a review of flight and duty time regulations for cabin crew from 38 ICAO member states. Findings showed that among all the rules included in these regulations, 49% of rules were associated with working hour limits, and 37% were associated with rest requirements, but only 6% of the rules were associated with circadian rhythm effects (the remaining 8% were categorized as 'other' rules) (Banks et al., 2009). The small number of rules addressing circadian effects included provisions for late finishes and early starts and were found in the regulations of 53% of the member states reviewed , whereas provisions for increasing rest time to facilitate time zone readjustment appeared only in the regulations of 47% of the member states reviewed (Banks et al., 2009).

The United States Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) are the two largest international regulatory authorities. They each have their own set of flight and duty time limitations, which for cabin crew are stipulated in FAA's Title 14 Code of Federal Regulation (CFR) Sections 121.467 and 135.273 (Code of Federal Regulations, 2018a, 2018b), and in EASA's Regulation No 83/2014 Section ORO.FTL.205 (European Aviation Safety Agency, 2014).

However, not all member states have prescriptive rules in place for managing cabin crew fatigue, including New Zealand and Australia. In these countries, the regulators have adopted a performance-based approach, enabling operators to specify the maximum work and minimum rest requirements, which are stipulated in employment contracts, and/or collective bargaining agreements (Banks et al., 2009).

Flight and duty time limits for cabin crew are typically less restrictive than those for flight crew. For example, in the FAA and EASA rules, provisions are included for cabin crew to report for duty an hour earlier than flight crew to accommodate pre-flight preparations and crew briefing, thereby extending their duty period (Code of Federal Regulations, 2018b; European Aviation Safety Agency, 2014). Such provisions were included in 22% of the 38 member states' regulations reviewed by Banks and colleagues (Banks et al., 2009). Yet compensation for this extended duty is not included in the rest period. In fact, under the FAA rule, minimum rest requirements for cabin crew are also less restrictive than for flight crew, with flight crew needing at least 10 hours rest following a duty period versus 9 hours rest for cabin crew (Code of Federal Regulations, 2018a, 2018b; Federal Aviation Administration, 2012).

With newer aircraft being able to fly more than 16 hours non-stop, flight operations can exceed the maximum limits of traditional flight and duty time regulations. Such flights present a challenge for airlines, as they can potentially increase fatigue-related operational risk, particularly during the later stages of the flight, if they lead to restricted sleep, extended periods of wakefulness, and/or high operational demands at sub-optimal times in the circadian body clock cycle.

1.9.2 Fatigue Risk Management Systems (FRMS)

Fatigue Risk Management Systems (FRMSs) are a relatively new approach to improving safety and increasing operational flexibility. Defined as "*a data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness*", FRMS is applicable to both flight crew and cabin crew (International Civil Aviation Organization, 2016).

FRMSs are modelled on the Safety Management System (SMS) framework (International Civil Aviation Organization, 2013; Maurino, 2017), and uses similar processes and procedures for managing fatigue as for other hazards.

1.9.2.1 FRM processes and other essential FRMS components

At the core of FRMSs are the fatigue risk management (FRM) processes, which form a closed process loop to deal with the day-to-day management of fatigue (illustrated as the left-hand loop in Figure 1-5). These processes are data-driven and involve the ongoing monitoring of fatigue levels to identify situations in which fatigue may be a hazard, assessment of the level of risk associated with a fatigue hazard, and mitigating the fatigue risk where warranted. Ongoing monitoring is also necessary to evaluate the effectiveness of introduced fatigue mitigations, and for identifying any new fatigue hazards (International Civil Aviation Organization, 2016).

Data for the FRMS process loop, needed for deriving safety performance indicators (SPIs) as key measures for ongoing monitoring, come from a variety of sources. These include routine operational data, for example planned versus actual schedules worked, and the number of fatigue reports filed by crewmembers. Some situations also require the monitoring of actual crewmember fatigue levels, for which different measures can be used to generate fatigue SPIs. The choice of these measures needs to reflect the anticipated levels of fatigue and safety risk, since this type of data collection is relatively time-consuming and resource-intensive in comparison to other, routinely collected operational data (Gander, Mangie, et al., 2014; Gander et al., 2017; International Civil Aviation Organization, 2016).

SPIs are not only used for the ongoing monitoring of fatigue risk, but also for tracking fatigue trends over time, and for evaluating the FRMS's performance in relation to its safety objectives, as illustrated as the right-hand loop in Figure 1-5 (Gander, Mangie, et al., 2014; Gander et al., 2017; International Civil Aviation Organization, 2016).

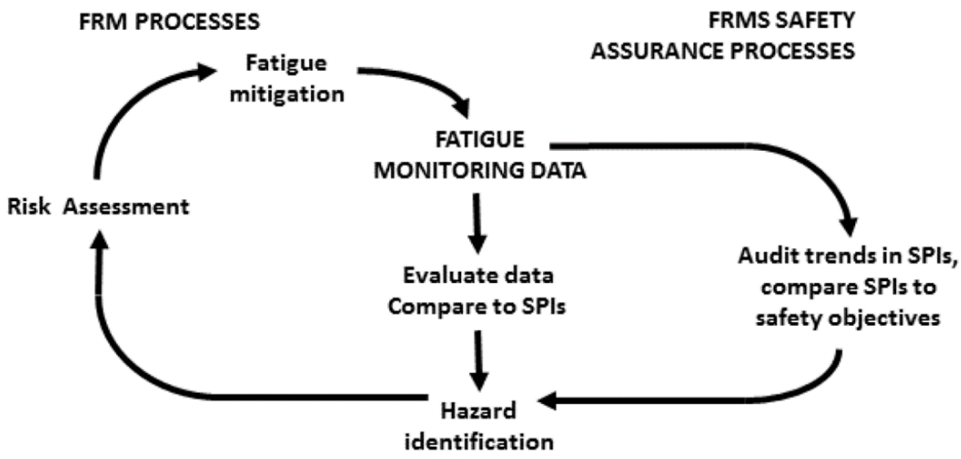

Figure 1-5 FRM processes and assurance loop (Gander, Mangie, et al., 2014)

In support of these FRM processes, other essential FRMS components include an FRMS policy that clearly outlines the shared responsibility among all stakeholders, and management's commitment to meet its FRMS safety objectives. All FRMS elements and activities must be documented to ensure the information is accessible for consultation, and for auditing (International Civil Aviation Organization, 2016).

In order to promote a positive safety culture throughout the company and achieve full involvement from all relevant personnel, effective safety communication, and the sharing of fatigue-related information across the company, from management to operational personnel, and vice versa, is essential.

These regular FRMS activities are the responsibility of a Fatigue Safety Action Group (FSAG), made up of representatives from all stakeholder groups, including management, crewmembers, union, scheduling, as well as any other groups within the company which make decisions that might affect the work of crewmembers.

An effective safety culture hinges on the voluntary reporting of hazards (International Civil Aviation Organization, 2013; Maurino, 2017), and in the case of FRMS, on the voluntary reporting of fatigue (International Civil Aviation Organization, 2016). This, in turn, requires that the organisation has adopted a no-blame or 'just culture', in which personnel can report occurrences without fear of punishment, as long as these were unintended, rather than the result of negligence, or wilful disregard for safety (International Air Transport Association, International Civil Aviation Organisation, & International Federation of Airline Pilots Associations, 2015; Maurino, 2017).

An FRMS also requires that everyone has an appropriate understanding of fatigue and its risks, the management thereof, and their role and responsibilities within FRMS. To enable the continuing improvement of a company's FRMS, fatigue management training, and effective FRMS communication are therefore fundamental (International Civil Aviation Organization, 2013, 2016; Lerman et al., 2012).

1.9.2.2 Managing fatigue risk associated with Ultra-Long Range (ULR) operations

To manage the fatigue risk associated with ultra-long range (ULR) flights, defined as flight operations between a specific city pair in which at least one of the flight sectors regularly exceeds 16 hours planned flight time (Flight Safety Foundation, 2005b), airlines are usually required to put in place an FRMS.

There are a number of fatigue hazards associated with ULR operations, as identified from the scientific principles described in this chapter, and operational experience (Flight Safety Foundation, 2003, 2005b). The long flight and duty times can lead to sleep loss, extended wakefulness, time-on-task fatigue, and also likely require crew to work during adverse times in the circadian cycle. Circadian disruption resulting from rapid time zone changes and adaptation to the layover time zone will also influence crewmembers' functioning and ability to sleep on the inbound flight, as well as their rate of recovery post-trip (International Civil Aviation Organization, 2016).

1.10 Importance and rationale for present study

While a large body of research exists on flight crew fatigue (Civil Aviation Authority, 2007; Gander, Rosekind, & Gregory, 1998), few field studies have monitored the fatigue of cabin crew and to date no published information is available on cabin crew fatigue on ULR flights, nor on FRMS processes specific to the needs of cabin crew.

The main fatigue mitigation strategy for ULR flights is to provide crewmembers with in-flight rest breaks and crew rest facilities in which they can obtain sleep. Current ULR scheduling for cabin crew is predominantly based on *flight crew* data, but due to requirement for all cabin crew to be awake for meal services, they have less time available for inflight rest compared to flight crew. In addition, in many countries the regulatory requirements for on-board rest facilities are less rigorous for cabin crew than for flight crew (Banks et al., 2009).

Current scheduling also does not take into consideration the relationship between workload and the high levels of fatigue frequently experienced by cabin crew (Nesthus et al., 2007; Samel et al., 2002; Vejvoda et al., 2001), which has possible implications for fatigue management (Dorrian, Baulk, & Dawson, 2011). Cabin crew workload is also considerably different in nature from that of flight crew, which may have implications for the rest provisions for cabin crew.

Finally, work-related fatigue is affected (negatively or positively) by activities outside of work as well as by work-related ones. In order to manage in-flight fatigue risk successfully, it is necessary that both the employer and employee understand all sources of fatigue and the potential consequences for safety. However, cabin crews' views on fatigue and their strategies for mitigating it, have seldom been sought (Avers, King, et al., 2009; Avers et al., 2011).

1.11 Study aims

The overall aim of this research project is to evaluate the current status of an FRMS specifically for cabin crew, and to determine its future needs. To achieve this, the following two research questions will be addressed:

Question 1: How effective are the FRM processes for managing cabin crew fatigue associated with a ULR trip?

Question 2: How do cabin crew feel about their sleep and fatigue, and how fatigue might affect how safely and well they can do their job, particularly in the context of ULR flying?

A mixed methods design will be used, combining quantitative and qualitative methodologies in two separate, 'parallel' studies. Specific study objectives and methodology can be found in Chapter 2.

1.12 Structure of this thesis

This thesis, which is structured around a quantitative ULR validation study and a qualitative focus group study, is presented as a thesis with publications. Consequently, there will be some repetition of information in each of the manuscripts' introductions. Additionally, by adhering to the journals' publication guidelines, the description of methodology in these manuscripts is very succinct.

Therefore, Chapter 2 provides a detailed description of the study design and methodology used. This chapter also outlines the study aims and research questions.

Chapter 3 contains the first quantitative paper, presenting key findings on the ULR validation study. This paper has been published in *Aerospace Medicine and Human Performance* (August 2015).

Chapter 4 contains the second quantitative paper, which examines the influence of perceived workload on cabin crew fatigue, using data collected during the ULR validation study. This paper has been published in *The International Journal of Aerospace Psychology* (June 2019).

Chapter 5 contains the third paper, which reports on the findings of the qualitative focus group study. This paper has been published in *Industrial Health* (April 2019).

The papers in Chapters 3-5 have been re-formatted to match the style used throughout this thesis and the references are included in the full reference list.

In Chapter 6, the findings from the preceding chapters are integrated and discussed in the context of ICAO's FRMS framework, Safety Management Systems theory, and occupational health and safety legislation, to highlight what currently works for cabin crew, and the gaps that this research has identified. The chapter concludes with recommendations for improvements, and suggestions for future research are proposed.

Supporting materials are included as Appendices A-Y.

CHAPTER 2 METHODOLOGY

2.1 Overview

This chapter provides a detailed description of the study aims, study design, and methodology used in this doctoral research. Due to the journals' stipulated word limit, many details were omitted from the Methods in each of the papers presented in Chapters 3-5.

2.2 Research questions

As previously outlined in Chapter 1, the overall aim of this research project is to evaluate the current status of an FRMS specifically for cabin crew, and to determine its future needs. To achieve this, the following two research questions will be addressed:

Question 1: How effective are the FRM processes for managing cabin crew fatigue associated with a ULR trip? Specifically:

a. Does cabin crew fatigue, sleepiness, or performance degrade during the course of a JNB-JFK-JNB trip?

b. When and how much are cabin crew sleeping on layovers?

c. When and how much are cabin crew sleeping in flight?

d. How many days post trip are required for fatigue and sleep to return to pre-trip levels?

e. Does perceived workload on a flight influence sleepiness, fatigue, and/or performance at top of descent?

Question 2: How do cabin crew feel about their sleep and fatigue, and how fatigue might affect how safely and well they can do their job, particularly in the context of ULR flying? Specifically:

a. What causes fatigue at home and at work?
b. How does fatigue affect them at home and at work?
c. Are there any safety-related tasks at work that are affected by fatigue?
d. How do they currently manage fatigue at home and at work?
e. What could be changed for cabin crew to reduce fatigue in flight?

2.3 Study design

To address these research questions, a mixed methods research design was used by combining the strengths of quantitative and qualitative methodologies in two separate, ‘parallel’ studies. By utilizing the different strengths of these methodologies, additional coverage was created to achieve a more complete understanding of cabin crew fatigue (Creswell & Plano Clark, 2011; Morgan, 2014). This design is summarized in Figure 2-1.

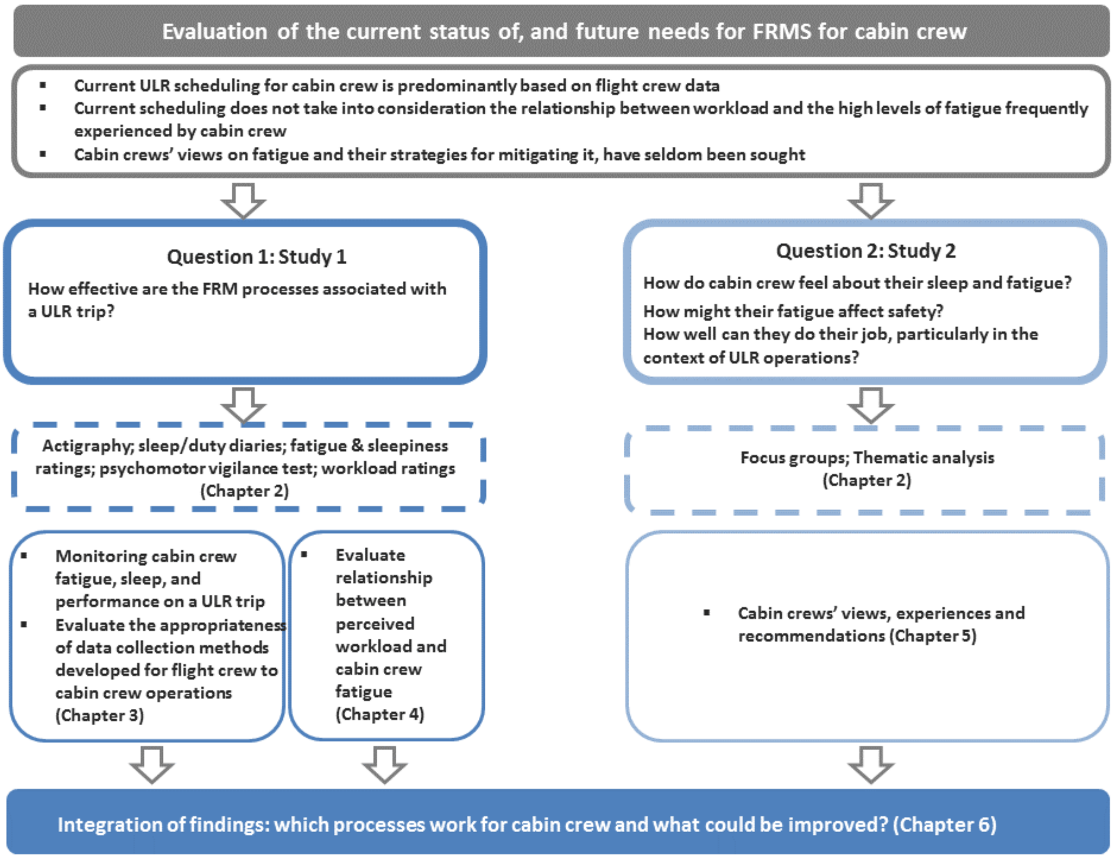

Figure 2-1 Diagram of thesis research mixed methods design

2.3.1 Theoretical framework

The purpose of conducting research is to find new knowledge that serves to answer a research question. Our understanding or belief of what constitutes knowledge, or epistemology, determines the type of knowledge that is being sought, which in turn determines the choice of research methodology and methods being used. It also determines how we value different types of knowledge (Crotty, 1998).

Quantitative and qualitative research methodologies are usually underpinned by different epistemological stances about what constitutes legitimate knowledge (Morgan, 2007). These epistemological stances form a continuum with Realism at one end and Relativism on the other end of the continuum. Realism assumes that separately from our own experiences or perceptions, a single reality exists that can be discovered and measured objectively. In contrast, Relativism assumes that reality is subjective, created by an individual's own experience and interpretation (Creswell & Plano Clark, 2011; Morgan, 2014).

Quantitative research, which is usually associated with realism, aims to accurately describe the 'real world' by making objective observations or measurements of specific variables, while minimizing the influence of the researcher. Summarized data enable comparisons to be made between participants, different groups and/or across time points, and can often be generalized to a broader range of people or settings (Creswell & Plano Clark, 2011; Crotty, 1998; Morgan, 2014; Pistrang & Barker, 2012). Qualitative research, on the other hand, is often associated with an epistemological stance that is situated further along the continuum towards Relativism. Its focus is on describing and interpreting participants' subjective experiences and views that are context-specific. The researcher being the research instrument, his/her own beliefs, and experiences will influence the data collection and analysis. Qualitative findings are usually not generalizable to other contexts (Creswell & Plano Clark, 2011; Morgan, 2007, 2014).

Bypassing these philosophical contradictions, a pragmatist stance (James, 1994; Morgan, 2014; Peirce, 1997) was adopted to guide this thesis research. 'Pragma' is the Greek word for 'action' and the principle of the pragmatist approach is to produce useful 'real world' knowledge that is solution-focused. It is therefore the research question that determines which methodology and methods are used. By focusing on 'what works', both objective and subjective knowledge are equally valued (Creswell & Plano Clark, 2011; Morgan, 2007).

To situate the present research within the existing knowledge of fatigue risk management, a pragmatist approach was adopted as a practical and applied research philosophy focused on producing 'real-world' knowledge that is solution-focused (Morgan, 2007). In addition, the theoretical framework that underpins FRMS is that of safety management systems (SMS) in aviation (International Civil Aviation Organization, 2016; Maurino, 2017; Maurino, Reason, Johnston, & Lee, 1998) and the present thesis research was guided by this framework.

2.3.1.1 The researcher's perspective

The organization and interpretation of textual material derived from talk will inevitably be affected by the researcher's views and background (Malterud, 2001).

I joined the Sleep/Wake Research Centre in 2001 and have since been involved in many field studies evaluating the sleep and fatigue of flight crew on long-range and ultra-long range flights (Gander, Signal, et al., 2013; Signal, Gander, et al., 2013; Signal, Mulrine, van den Berg, Smith, & Gander, 2013; van den Berg, Signal, Mulrine, et al., 2015). For one study, this involved joining the crew on several ULR trips (Signal et al., 2004), which offered me a great insight into the challenges that not only flight crew, but also cabin crew were faced with on these trips. Combined with two years' experience as a sleep technician working shift work, I have gained personal experience of the challenges associated with fatigue and circadian disruption at work as well as outside of work. My existing knowledge and experiences have influenced all aspects of the focus group study, including my motivation to conduct this study, the study design, interaction with the participants, and data analysis.

2.4 Ultra-long range validation study (Study 1)

A repeated measures study design was used with measures and data collection procedures that follow accepted international best practice for fatigue monitoring in aviation operations (Flight Safety Foundation, 2003, 2005b; International Civil Aviation Organization, 2016).

2.4.1 Ethical considerations

This study was reviewed and approved by the Massey University Human Ethics Committee: Southern A (Application 11/74) in 2011, which covered both the South African Airways ULR validation study for flight crew (not part of this thesis) and for cabin crew. Subsequently, approval was obtained for several minor amendments, as follows. To facilitate the inclusion of this study in my doctoral research, the following statements were added to the participant information sheet:

"Completion of this study will contribute towards Margo van den Berg's Doctoral degree, under supervision of Dr Leigh Signal and Professor Philippa Gander."

"Additionally, de-identified data from all cabin crew in this study may subsequently be used for additional analyses".

Additionally, changes were made to the timelines in the sleep/duty diary, and the timing of performance tests in-flight, to improve data quality. The final minor amendments were approved in February 2013 (see Appendix A).

A number of risks were identified that could arise from participating in the study, as follows.

In the unlikely event of a safety incident occurring during a flight on which a crewmember is participating, outside agencies investigating the incident could request to review a participant's actigraphy, diary and performance data. To minimize this risk, all data was de-identified and coded using study ID numbers. Researchers at the Sleep/Wake Research Centre did not have data linking participant names and ID numbers. Members of the research team at SAA did not have access to the data, except for one designated SAA member of the research team who downloaded actigraph and performance data to a computer, scanned sleep/diaries and uploaded the raw data files to a secure ftp site, for access by researchers at the Sleep/Wake Research Centre. Information held by the SAA research team which linked participants' names with ID numbers, was destroyed on completion of data collection. As well as providing the usual confidentiality and privacy protection to participants' data, these measures made it almost impossible for the research team to provide data from a particular participant to an external agency.

A minor risk of discomfort from wearing the actigraph was outlined in the participant information sheet (Appendix B). Data confidentiality was strictly maintained by storing data in a de-identified format, using a unique identification number for each participant.

The information sheet also outlined the participant's right to withdraw from the study at any time without consequences. Participants could also ask to have any of their personal data handed back to them and have their data removed from all datasets at any time. Participation was voluntary and informed, written consent (Appendix C) was obtained prior the participant's participation.

2.4.2 Participants and recruitment

All cabin crew who were scheduled to fly the JNB-JFK-JNB ULR trips during the study period were eligible to participate. The total number of cabin crew working at the airline during this time was approximately 1500. No compensation was offered for participation.

The aim was to recruit 50 participants, as determined by power calculations (Appendix D).

Information on the study was initially advertised via the airline company's communication channels. From this initial notification, interested crewmembers could contact a SAA member of the study team for further information. Crewmembers scheduled for a JNB-JFK-JNB trip during the study period were telephoned by a SAA member of the study team and invited to participate. Up to seven of the 14 cabin crew rostered for a flight were invited to participate, since it was considered important to sample a range of flights in case conditions varied widely from one flight to the next, or in the event of peculiarities on one particular flight (e.g., delays, turbulence, medical event). The phone call also provided an opportunity for the study requirements to be explained and for potential participants to ask questions.

Interested crewmembers were sent an introductory package containing information on the study (Appendix B) and a consent form (Appendix C). Those willing to participate returned the signed consent form to the SAA member of the research team.

2.4.3 Monitoring sleep

The gold standard for objectively monitoring human sleep is polysomnography (PSG), which at a minimum comprises three different physiological measures, namely electro-encephalogram (EEG) for recording brain wave activity, electro-oculogram (EOG) for recording eye movement, and surface electromyogram (EMG) for recording muscle tone (Carskadon & Rechtschaffen, 2005). Using scoring criteria developed by the American Academy of Sleep Medicine (Berry et al., 2015), these measures together enable the staging of sleep for determining total sleep and wake time, sleep onset latency, and aspects of sleep quality including sleep efficiency (Carskadon & Rechtschaffen, 2005). However, monitoring sleep with PSG is time-consuming, costly and intrusive to the participant, and unsuitable for field studies monitoring sleep patterns across multiple days or weeks.

2.4.3.1 Actigraphy

Actigraphy is a validated, widely used alternative method for monitoring sleep in many different populations (Ancoli-Israel et al., 2003; Sadeh, 2011), including cabin crew (Grajewski, Whelan, Nguyen, Kwan, & Cole, 2016; Lowden & Åkerstedt, 1998a, 1998b, 1999; Roma et al., 2010; Vejvoda et al., 2000; Vejvoda et al., 2001). It has also been used in ULR validation studies involving flight crew (Gander, Signal, et al., 2013; Holmes, Al-Bayat, Hilditch, & Bourgeois-Bougrine, 2012; Signal et al., 2014).

Because actigraphy is low-cost and minimally intrusive, it is ideal for monitoring sleep patterns in field-based studies across days or even weeks. Furthermore, because sleep patterns can be monitored continuously for extended periods of time, actigraphy is also useful for identifying circadian disruption to the sleep-wake cycle (Ancoli-Israel et al., 2003; Gander et al., 2016; Gander, van den Berg, Mulrine, Signal, & Mangie, 2013; Grajewski, Nguyen, Whelan, Cole, & Hein, 2003; Lowden & Åkerstedt, 1998a, 1998b, 1999; Roach, Rogers, & Dawson, 2002), for example by evaluating changes in sleep timing and sleep duration.

Typically the size of a wristwatch, the actigraph contains an accelerometer that detects and records movement. Based on the principle that little movement occurs during sleep relative to wake, a computer-based, validated scoring algorithm analyses patterns of activity and inactivity for estimating sleep- and wake patterns (Ancoli-Israel et al., 2003; Sadeh, 2011).

Validation studies comparing actigraphic sleep to PSG-recorded sleep epoch-by-epoch have shown that for sleep duration the overall agreement between measures is generally high (>90%) in healthy young adults (Ancoli-Israel et al., 2003; Sadeh, 2011). However, actigraphy is more reliable in detecting sleep (sensitivity) than it is in detecting wake (specificity) during a sleep period (Kushida et al., 2001; Sadeh, 2011), and less accurate when sleep is more disturbed (Ancoli-Israel et al., 2003). Because actigraphy cannot discriminate between still wakefulness and sleep, actigraphic measures of sleep efficiency (the proportion of actual sleep obtained during the sleep period) and sleep onset (the time it takes to fall asleep) are typically less reliable (Ancoli-Israel et al., 2003).

Notably, many of the validation studies have evaluated nighttime sleep (de Souza et al., 2003; Kushida et al., 2001; Lichstein et al., 2006; Sadeh, Sharkey, & Carskadon, 1994), although some have also included daytime sleep in their evaluation (Marino et al., 2013; Paquet, Kawinska, & Carrier, 2007; Reid & Dawson, 1999). This is of relevance in the present study since cabin crew frequently sleep during daytime hours because of their irregular work pattern. These studies showed that actigraphy remains a reliable tool for monitoring daytime sleep duration, although accuracy might slightly decrease with increasing age (Marino et al., 2013; Paquet et al., 2007; Reid & Dawson, 1999). However, these studies had in common that they took place in a laboratory-based setting, free from environmental disturbances so that sleep may have been less disrupted than sleep at home. Furthermore, differences in data acquisition technologies and sleep scoring algorithms, and sensitivity settings applied by the user can also influence the reliability of actigraphy (Ancoli-Israel et al., 2003; Gorny & Spiro, 2001; Kushida et al., 2001; Marino et al., 2013; Signal, Gale, & Gander, 2005).

One field-based study compared actigraphic sleep to PSG-recorded sleep recorded from 21 pilots sleeping in a layover hotel and in flight in order to evaluate the reliability of actigraphy in these conditions (Signal et al., 2005; Signal, Gander, et al., 2013). Using the AW64 Actiwatch and Actiware-Sleep software (Mini Mitter Co, Inc), which are earlier versions of the actigraph and software used in this thesis research, data was recorded and subsequently analyzed using three different sensitivity settings (low; medium; high). Sleep onset was determined as the start of the first 20 minutes in which 19 minutes had zero activity, and sleep offset as the end of the last 10 minutes with zero activity. Comparisons were made between equivalent summary variables (duration; efficiency; latency) as well as epoch-by-epoch. Results indicated that on average, actigraphic sleep duration did not differ from PSG in either sleep location when the former was analyzed using the medium sensitivity setting. In contrast, the low setting underestimated layover sleep duration whereas the high setting overestimated in-flight sleep duration.

At the medium sensitivity setting, actigraphy reliably estimated average sleep duration of groups of pilots both in flight (agreement = 75.9%; sensitivity = 88.3%; specificity =46.6%) and in the layover hotel (agreement = 86.7%; sensitivity =91.4%; specificity =49.7%) (Signal et al., 2005). However, the 95% confidence intervals of the mean differences between the two measures were wide, indicating that actigraphy is less accurate at predicting the sleep of an individual, which could vary by at least one hour from PSG estimates. In addition, actigraphic estimates of sleep latency and sleep efficiency were not reliably related to PSG measures. Therefore, only sleep duration will be reported in this thesis research.

In the present study, the Actiwatch Spectrum (Philips, Respironics, Bend, Oregon, USA) was used, which has been shown to be reliable for estimating total sleep time when compared to PSG (Kripke et al., 2010; Mantua, Gravel, & Spencer, 2016; Marino et al., 2013). This model actigraph has a functional watch face (Figure 2-2), an event marker that the wearer can push to mark the start- and end times of rest periods, and a light sensor for recording information on light exposure. The device was programmed to display the current time as Universal Time Coordinated (UTC) to make it easier for participants to record their bed- and rise times across the study period in UTC, in the accompanying sleep/diary. The light function was however disabled to minimize the risk of filling the device's memory during the data collection. An additional feature of this actigraph is its ability to detect when the watch is worn against skin (provided the distance between the device's surface and skin is less than 2 millimetres), which provides an additional source of information during the scoring of actigraphy. The device is powered by a CR 2430 Lithium Coin Cell, which enables continuous data collection for up to 8 months, after which it needs replacing by the manufacturer.

The Actiwatch Spectrum contains a solid-state piezoelectric accelerometer, which integrates the intensity and frequency of physical movement to produce a voltage. These voltages are sampled at 32 Hz (i.e. 32 times per second) and filtered using a band pass filter of 0.35 - 7.5 Hz, to reduce the influence of non-physiological artefact such as drift, electrical noise or external vibrations e.g. from operating a motor vehicle (Chen & Bassett, 2005). Voltages are then digitized[2] to create an activity count. This activity count is the sum of the peak activity values for each second of data monitored over an epoch, which in the present study was set to 1 minute.

Figure 2-2 Image of Actiwatch Spectrum (Philips, Respironics) actigraph

Traditionally, the actigraph is placed on the non-dominant wrist. Although a number of studies have shown that more activity is recorded by actigraphs placed on the dominant hand than by those on the non-dominant hand (Middelkoop, van Dam, Smilde-Van Den Doel, & van Dijk, 1997; Sadeh et al., 1994), concordance with PSG is high for recordings from either wrist (Sadeh et al., 1994). However, to reduce measurement error in the recordings,

[2] Specific details are proprietary to Philips Respironics.

placement of the actigraph was standardized and participants were asked to wear the actigraph on their non-dominant wrist throughout their participation.

Actigraphy recordings are subsequently analyzed using a computer software algorithm that has been validated against PSG to ensure its accuracy (Ancoli-Israel et al., 2015). The Actiware (version 5.71.0, Philips Respironics, Bend, Oregon, USA) software algorithm scores each 1-minute epoch of data within a rest interval as either sleep or wake. To be identified as a wake epoch, the activity count for that particular section of data, plus weighted contributions from surrounding epochs (Figure 2-3) must exceed the predetermined sensitivity value. In this thesis research, the medium sensitivity setting was used with 40 activity counts as the threshold value. This setting was chosen as it has previously been shown to provide the most accurate relationship with PSG when flight crew are sleeping in either a hotel or in flight (Signal et al., 2005).

Using the program's default settings, sleep onset is automatically determined as the first 10 minutes of the rest interval in which no more than one epoch contained activity. Similarly, to estimate sleep offset, the software algorithm searches for the final 10 minutes containing no more than one epoch with activity, where the last minute of that period is determined as the end of sleep. Because quiet wakefulness precedes the onset of sleep, actigraphy usually underestimates PSG-determined sleep latency (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992). Although a 20-minute sleep onset criterion has been shown to provide the most accurate estimate for PSG-determined sleep onset in nocturnal sleep (Cole et al., 1992), using a longer than 10-minute criterion has also been shown to produce shorter estimates for sleep duration (Chae et al., 2009). Adopting a longer sleep onset criterion in the present thesis research would limit the scoring of any sleep during short nap opportunities.

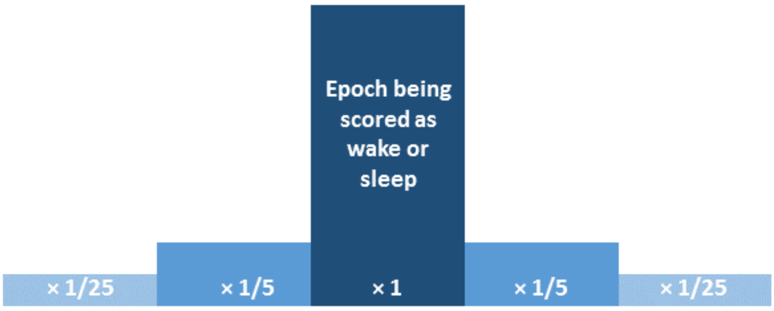

Figure 2-3 Weighting of activity counts in 1-minute epoch (reproduced from Philips, Respironics)

2.4.4 Measuring subjective sleepiness and fatigue

Two subjective rating scales that have been recommended for use in aviation FRMS are the Karolinska Sleepiness Scale and Samn-Perelli Crew Status Check (International Civil Aviation Organization, 2016). One limitation of these self-reports is that they may not reliably reflect objective assessments of performance impairment under higher levels of sleepiness, particularly following chronic sleep restriction, due to a diminishing ability to accurately assess one’s internal state under higher levels of sleepiness (Belenky et al., 2003; Van Dongen et al., 2003).

2.4.4.1 Karolinska Sleepiness Scale

The Karolinska Sleepiness Scale (KSS) was used to obtain participants’ momentary self-assessment of their sleepiness. It is a nine-point Likert-type scale with verbal descriptions at the following points: 1= ’extremely alert’, 3= ‘alert’, 5=’neither alert nor sleepy’, 7=’sleepy, but no difficulty remaining awake’, and 9= ’extremely sleepy, fighting sleep’ (Åkerstedt & Gillberg, 1990; Gillberg, Kecklund, & Åkerstedt, 1994; Härmä, Sallinen, Ranta, Mutanen, & Muller, 2002). This scale has been extensively used in measuring an individual’s perception of sleepiness, both in laboratory (Åkerstedt & Gillberg, 1990; Sargent, Darwent, Ferguson,

& Roach, 2012; Van Dongen et al., 2003; Wyatt, Cecco, Czeisler, & Dijk, 1999) and field studies (Gander, Mulrine, van den Berg, Smith, Signal, et al., 2014; Gander et al., 2015; Gillberg et al., 1994; Härmä et al., 2002). These studies have shown that KSS ratings increase across wakefulness and vary with circadian phase, so that ratings are highest during the biological night following sleep loss. In controlled laboratory studies, significant linear relationships were found between KSS ratings and vigilance task performance metrics (slower reaction times and more lapses on the Psychomotor Vigilance Task – see Section 2.4.5.1 below) (Kaida et al., 2006). KSS ratings of 7 and above have also been associated with the occurrence of very short periods of uncontrolled sleep, or microsleeps (Åkerstedt & Gillberg, 1990).

2.4.4.2 Samn-Perelli Crew Status Check

Fatigue was rated on the Samn-Perelli Crew Status Check (SP), which is a 7-point Likert-type scale with verbal descriptions at each point, as follows: 1= 'fully alert, wide awake', 2='very lively, responsive, but not at peak', 3='okay, somewhat refreshed', 4='a little tired, less than fresh', 5='moderately tired, let down', 6='extremely tired, very difficult to concentrate', and 7= 'completely exhausted, unable to function effectively' (Samel, Wegmann, & Vejvoda, 1997; Samel, Wegmann, Vejvoda, et al., 1997; Samn & Perelli, 1982). The SP was developed specifically for use with military airlift flight crew (Samn & Perelli, 1982) and has been used in many flight crew studies focused on sleep loss, fatigue, and performance (Gander, van den Berg, Jay, & Signal, 2011; Pascoe et al., 1994; Pascoe et al., 1995; Robertson et al., 1997; Signal et al., 2004; Spencer & Roberston, 2000). In a 28-hour forced desynchrony study, circadian phase was shown to influence both pre-sleep and post-sleep SP ratings, and the degree of sleep restriction influenced post-sleep SP ratings (Ferguson et al., 2012). However, no studies to date have systematically evaluated the SP against objective measures of performance (Gander et al., 2017).

2.4.5 Measuring performance

The degree of performance degradation associated with sleep loss and circadian phase varies depending on the type of task involved, with larger effects seen for simpler tasks (Lim & Dinges, 2008; Lo et al., 2012; Wickens, Hutchins, Laux, & Sebok, 2015). Among these simpler tasks, the Psychomotor Vigilance Task (PVT) is often used as a 'gold standard' measure (Banks et al., 2017; Van Dongen, Balkin, & Hursh, 2017).

2.4.5.1 Psychomotor Vigilance Task

The Psychomotor Vigilance Task (PVT) (Dinges & Powell, 1985) is a "simple" reaction time test, in that it does not involve a choice between responses. It measures the ability of an individual to sustain attention and respond rapidly when presented with information. This aspect of performance is considered a fundamental component of more complex tasks. However, it should not be considered a measure of more complex performance and skills such as decision-making and team work (Gander et al., 2017; Petrilli, Thomas, Dawson, & Roach, 2006).

A major advantage of the PVT is that it has virtually no learning curve, except to allow for familiarisation with the testing device (Doran et al., 2001).

In laboratory-based studies, the PVT has been shown to be highly sensitive to acute sleep loss, chronic sleep restriction, and the modulating effects of the circadian body clock (Belenky et al., 2003; Lo et al., 2012; Van Dongen et al., 2003; Zhou et al., 2011).

The most commonly used version of the PVT involves the presentation of visual stimuli and is 10 minutes in duration (Basner & Dinges, 2011). More recently, a 5-minute version of the PVT has been shown to be comparable to the 10-minute version in terms of sensitivity to the effects of sleep loss and circadian variation in laboratory-based studies (Lamond et al., 2008; Roach, Dawson, & Lamond, 2006; Thorne et al., 2005) . This shorter test version has been used in recent field studies with pilots and cabin crew to reduce disruption to crews' workflow (Gander, Signal, et al., 2013; Roach, Petrilli, Dawson, & Lamond, 2012; Roma et al., 2010; Signal et al., 2014).

In this thesis research, a validated 5-minute version of the PVT (PalmPVT) (Thorne et al., 2005) was used, installed on a Palm Centro Smartphone (Palm, Inc., Sunnyvale, California, USA), as shown in Figure 2-4 below.

Figure 2-4 PalmPVT on Palm Centro device

The PalmPVT test requires a participant to attend to a display and respond by pushing a button as soon as a stimulus appears (the stimulus is a "bulls-eye" symbol with numbers in the centre that represent response time counting in milliseconds). The participant receives immediate feedback each time the response button is pushed by a brief display of the number of milliseconds taken to respond. After a random time interval (between 2-10 seconds), the stimulus reappears and the participant is required to respond again. Stimuli were presented in this manner for 5 minutes, yielding approximately 45 responses per test.

To standardize test conditions, participants were instructed to perform this test in a quiet and evenly-lit place without distractions, to hold the device comfortably with both hands, and respond by using the thumb or finger of their dominant hand, consistently across all tests (Ambulatory Monitoring Inc; Roach et al., 2006).

Four commonly reported performance metrics from this test were used in the present thesis research, namely:

- Response speed (1/reaction time ×1000)
- The slowest 10% of responses (1/reaction time ×1000)
- The fastest 10% of responses (1/reaction time ×1000)
- Lapses (reaction times exceeding 500ms in duration)

Optimum and intermediate performance is difficult to maintain under conditions of sleep loss. Optimum performance is reflected in the fastest 10% of responses whereas overall response slowing is reflected in the mean response speed metric. By using the reciprocal transform, the influence of long responses are reduced, while emphasizing small changes in the faster responses (Basner & Dinges, 2011).

A period of inattentiveness is reflected in the occurrence of a lapse, which become more frequent and longer in duration with increasing sleep loss.

Performance also becomes more variable with an increasing number of slower responses interspersed with 'normal' ones. This change is reflected in the 10% slowest of responses, which includes responses exceeding 500ms, i.e. lapses. The reciprocal transform was used to decrease the contribution of long lapses (Basner & Dinges, 2011; Lim & Dinges, 2008).

Only valid responses (reaction times ≥ 100ms) were included in the analyses, generating approximately 45 responses per test.

2.4.6 Measuring workload

Workload is a multi-dimensional concept resulting from an interaction between task-related aspects (task difficulty, complexity, and intensity), person-related aspects (experience, skill level, internal state such as fitness, and traits such as cognitive processing capabilities), as well as temporal aspects (time on task; time pressure) (Casner & Gore, 2010; Gaillard, 2001; Hart & Staveland, 1988; Lysaght et al., 1989). Due to this complexity, workload has been operationalized in various ways, for example by making a distinction between physical workload versus mental workload, or between objective workload versus perceived workload. This, in turn, will determine the type of measure used for assessing workload (Bowling & Kirkendall, 2012; Casner & Gore, 2010; Gaillard, 2001; Hart & Staveland, 1988; Lysaght et al., 1989).

Objective measures of workload include those that measure a physiological aspect that is expected to vary with the demands of the task (e.g. cardiac activity), and those that assess performance, such as speed, accuracy or action (e.g. number of steps taken). These objective measures have in common that they do not consider the individual's capacity at the time of performing the task. Subjective measures, on the other hand, assess workload as it is experienced by the individual and may therefore provide a more valid and practically useful indicator of workload. The amount of workload experienced by the individual is inversely related to the size of the gap between his/her available capacity to complete the task, and the amount of resources needed to do so (Casner & Gore, 2010; Hart & Staveland, 1988; Macdonald, 2003).

Using a subjective workload measure introduces the possibility that the supposed effects of workload, such as fatigue, might in fact become a cause of workload (Bowling & Kirkendall, 2012). For example, one study showed that ratings of effort after completing a complex simulation task were significantly increased following one night of sleep deprivation compared to the same task being completed after a normal night's sleep, as a means to maintain performance (Hockey, Wastell, & Sauer, 1998). However, another study showed that compared to a full night's sleep, sleep restriction either during the first or second half of the night did not significantly increase ratings of perceived exertion after intermittent physical exercise (Mejri et al., 2014). Nevertheless, a possible bi-directional relationship needs to be considered when interpreting associations between workload and fatigue.

2.4.6.1 NASA Task Load Index

The NASA Task Load Index (NASA TLX) is a multi-dimensional rating scale that was originally developed for use with flight crew (Hart & Staveland, 1988). Among four commonly used subjective workload scales, the NASA TLX has been shown to be the most sensitive to operator workload of military pilots (Hill et al., 1992). It has been used in a wide range of workplace settings to evaluate the influence of workload on fatigue (Baulk et al., 2007; Dorrian et al., 2011; Young, Zavelina, & Hooper, 2008), including studies with cabin crew (Roma et al., 2010; Vejvoda et al., 2000).

The NASA TLX consists of six sub-scales, measuring mental demands, physical demands, temporal demands (i.e. time pressure), quality of one's own performance, effort and frustration (see Appendix E, page 250. Each bipolar sub-scale, anchored with the verbal descriptions 'Low' to 'High', except for the performance sub-scale which is anchored with the verbal descriptions 'Good' to 'Poor', is divided into twenty equal intervals. Participants are instructed to place an 'X' in the position that best describes their experience. The 21 vertical tick marks on each sub-scale provide a scale from 0 to 100, in 5-step increments. For marks placed between two ticks, the score is rounded up to the tick on the right. An overall workload index is obtained by averaging the six sub-scale scores (Hart & Staveland, 1988) .

The NASA TLX includes a weighting component, which participants need to complete prior to conducting the work or task to be assessed. This weighting component is used to account for any individual differences in the subjective experience of the task. However, in more recent studies, this component is commonly eliminated to simplify the use of this workload measure (Hart, 2006). Several studies have shown that without the weighting component, the modified NASA TLX, also known as the raw TLX, is equally sensitive compared to the original version (Byers, Bittner, & Hill, 1989; Moroney, Biers, Eggemeier, & Mitchell, 1992). Based on these findings, and the importance of minimizing the study burden on participants, the weighting component was omitted in the present study.

2.4.7 Sleep/Duty Diary

A sleep/duty diary (Appendix E), developed by researchers at the Sleep/Wake Research Centre and used in many studies including those of flight crew, was adapted for use in the present study by including the raw NASA TLX and a Post Duty Service Questionnaire. In the pre-study questionnaire, questions regarding professional experience were modified to reflect the work of cabin crew. In addition, a Post Duty Service Questionnaire was included, which has been used in a previous cabin crew fatigue study (Roma et al., 2010). The following items were included in the diary:

- Instructions on when to complete specific sections of the diary.
- Information on wearing the actigraph and providing associated information in the sleep/duty diary.
- Information on completing the PVT.
- A pre-study questionnaire, which was adapted from one used for flight crew in multiple previous airline studies (Gander, van den Berg, et al., 2011; Signal, Gander, & van den Berg, 2003; Signal et al., 2004), included items on crew position, flying

experience, age, usual sleep at home on days off duty, usual sleep in on board crew rest facilities and in-flight fatigue.

- A lookback report, to document work history in the week prior to the start of data collection.
- For each of the 3 days prior to the outbound leg of the study trip, a timeline for recording sleep episodes, with spaces to rate sleep quality, fatigue, and sleepiness.
- One page to be completed prior to the flight and at top of climb (TOC), with items on scheduled and actual duty start, crew position for the flight (Galley, Aisle, Premium, Economy), planned rest breaks for the flight, and how the crewmember usually manages fatigue on this flight. There was also space provided for fatigue and sleepiness ratings, to be completed prior to take-off and at TOC, as well as space to indicate the time at which the pre-flight and TOC performance tests were taken.
- One page for the in-flight period, with a timeline for recording rest breaks and sleep episodes and spaces for noting when and where sleep was taken, and to rate sleep quality, fatigue, and sleepiness.
- One page to be completed at TOD and post flight, with items on time on blocks and off duty and with space for fatigue and sleepiness ratings to be completed at TOD and after landing.
- One page to be completed after landing, with the raw TLX, and Post Duty Service Questionnaire, to document:
    - The number of passengers on the flight;
    - Whether the flight was delayed;
    - If turbulence was experienced;
    - If there were disruptive passengers;
    - Medical or emergency incidents;
    - Major service disruptions; and

  - Number of times they assisted with baggage.
- For each 24-hour layover period, a timeline for recording up to four sleep episodes and spaces to rate sleep quality, fatigue, and sleepiness.
- Identical pages for the pre-flight and TOC, in flight, TOD, and post-flight phases of flight on the inbound flight.
- For each of the five days at home after the study trip, a timeline for recording sleep episodes, with spaces to rate sleep quality, fatigue, and sleepiness.
- A table to assist with time zone conversions.

2.4.8 Procedure

Data collection began 27 August 2012 and ended on 24 June 2013. There was a gap in the data collection period during the month of January because the lifespan of the Spectrums' batteries were shorter than anticipated and required replacement by the manufacturer.

At least 4 days prior to the departure of the study trip, participants were sent a sleep/duty diary, actigraph, and a Palm Centro containing the 5-minute PalmPVT. One of two response buttons (either left or right) was set according to the participant's handedness.

Where possible, a SAA member of the study team met with participants face-to-face to explain the study requirements and the use of the equipment. Alternatively, this was completed over the phone and the SAA member of the study team was available (via telephone or e-mail) to answer any questions. During this study briefing, participants were asked to familiarize themselves with the Palm Centro and PalmPVT and complete a practice test.

Participants were asked to complete the sleep/duty diary and wear the actigraph:

- For 3 days prior to the study trip; and

- The entire duration of the study trip, including in-flight legs and during the layover; and
- For 5 days after returning from the study trip.

As illustrated in Figure 2-5, participating crewmembers were asked to complete the following at various times:

- Pre-flight: in the briefing room prior to the flight (or as close as possible prior to this): details on the pre-flight and TOC page of the sleep/duty diary including SP and KSS ratings, and complete a PVT;
- At TOC, or within 90 minutes from take-off, after the seatbelt sign is turned off[3]: details on the pre-flight and TOC page of the sleep/duty diary including SP and KSS ratings, and complete a PVT.
- At the beginning of each in-flight rest period: details on the in-flight page of the sleep/duty diary including SP and KSS ratings;
- At the end of each in-flight rest period: details on the in-flight page of the sleep/duty diary including SP and KSS ratings;
- At TOD, or at the end of the last meal service, within 90 minutes before landing: details on the 'TOD and Post-flight' page of the sleep/duty diary including SP and KSS ratings, and complete a PVT;

[3] As this is a busy time for cabin crew, the 90-minute time window offered some flexibility for completing the PVT and ratings, thus reducing the risk of missing data.

- After landing and prior to disembarking: additional details on the 'TOD and Post-flight' page, including SP and KSS ratings after landing, and on the 'Post-Flight' page of sleep/duty diary the raw TLX and Post-Service Duty Questionnaire.

These times are summarized in Figure 2-5. The 14 cabin crew (including one senior purser and two pursers) who operate the A340-600 aircraft on the JNB-JFK-JNB route work as A and B crews who alternate their periods of duty and rest, with the B crew taking the first and third break on the outbound flight.

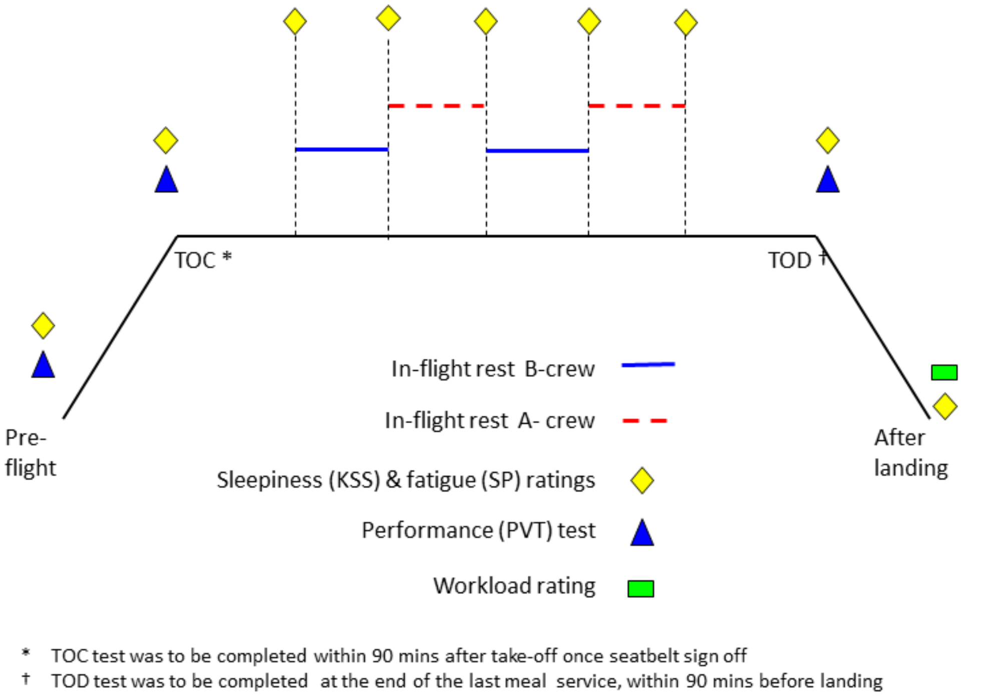

Figure 2-5 Times at which crewmembers completed ratings and performance tests

At the end of their participation, participants were asked to return their completed sleep/duty diary, actigraph, and Palm Centro to a SAA member of the study team.

At the completion of the study, participants were provided with a summary of the study findings (Appendix F).

2.4.9 Data management & analysis

Sleep/duty diaries, actigraph and PVT data were labelled with a unique crewmember identification number, which were assigned by the SAA member of the study team who held the identifying crewmember information. This research team member downloaded actigraph and PVT data to a computer, and uploaded the raw data files to a secure ftp site, which could be accessed by researchers at the Sleep/Wake Research Centre. Completed sleep/duty diaries were scanned and uploaded to the ftp site. As required in the ethical approval for the study, all paper diaries and consent forms were stored separately in a lockable cabinet at SAA and forwarded to the Sleep/Wake Research Centre for archiving once data collection was completed. All database development and data analyses were undertaken at the Sleep/Wake Research Centre.

2.4.9.1 Sleep/Duty Diary

All data entries were crosschecked by a second independent researcher and discrepancies (0.1%) were reviewed and rectified. Data tables were subsequently imported into SPSS (version 21.0, IBM SPSS Statistics for Windows, Armonk, NY, USA) for calculating new variables based on existing variables (.e.g. duty duration, based on duty start- and end time). Mean raw TLX scores were calculated in SAS software (version 9.3, SAS Institute Inc., Cary, NC, USA) by averaging scores on each of the six sub-scales. Where data was missing for one or more sub-scales, the mean raw TLX score was treated as missing (6.4%). Rates of missing data for KSS and SP completed pre-flight (14.5%; 11.3% respectively), at TOC (18.2%; 17.3%), at TOD (21.8%; 20.9%), and after landing (14.5% for both) were attributed to operational demands interfering with the study requirements.

2.4.9.2 Actigraphy

Individual actigraphy records were viewed using Actiware software (version 5.71.0, Philips Respironics, Bend, Oregon, USA). Periods spent trying to sleep (rest intervals) were manually determined using three sources of information, namely change in the level of activity, the event marker, and rest start times and end times recorded in sleep/duty diary.

Figure 2-6 shows a scored actigraphy file for one study participant. Details on actigraphy scoring rules can be found in Appendix G.

Where a participant had not worn the actigraph during a sleep period, but had recorded bed- and rise time in the sleep/duty diary, the corresponding interval was scored as 'Excluded' in the actigraphy file. The Actiware software produces only start- and end times for 'Excluded' intervals, which enabled the calculation of 'time in bed' for these intervals.

To assess the reliability of the manual identification of rest intervals, 20% of files were double-scored by a second independent trained researcher. Discrepancies of more than 15 minutes occurred in 10.9% of start times and 7.8% of end times. These were all double-checked and any errors were corrected. An overall agreement (agreement being classed as 15 minutes or less difference between scorers) of 90.7% was achieved.

The rest intervals were then analyzed using the Actiware software algorithm, using the medium sensitivity setting. Sleep intervals were defined as times between sleep onset (the first of 10 consecutive epochs scored by the algorithm as sleep) and final wakeup. Total sleep time was calculated as the number of minutes of sleep within the sleep interval (i.e. excluding any minutes scored as wake). Actigraphy variables were exported from the Actiware program into SPSS and SAS databases for statistical analysis.

A '*Darwent*' plot[4] was created using a custom-built MS Excel program, to illustrate the overall pattern of sleep and work for all participants across the study period (see Chapter 3, Figure 3-1).

[4] Named after Dr David Darwent at the University of Central Queensland, Adelaide, Australia, who generously shared his software for plotting sleep and duty times for each crewmember across the study trip

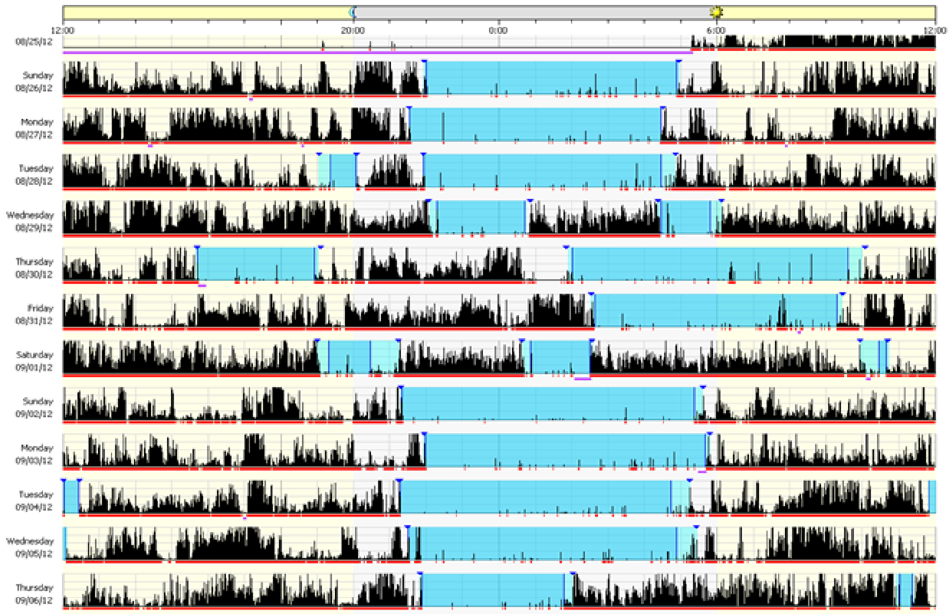

Figure 2-6 Example of a scored actigraphy record

Height of the black vertical lines indicates the amount of movement per minute; light blue = rest interval determined by scorer; dark blue = sleep interval determined by software algorithm; red = wake time as determined by software algorithm

Actigraphy variables were also exported from the Actiware program into a custom-built program (Actisoft 2.0[5]) in MS Access software (2010, Microsoft Corporation). This program was used to sum variables across 24-hour intervals, as follows.

- Baseline[6] sleep: total sleep per 24 hours from 72-24 hours preceding noon on the day of departure;
- Pre-flight sleep: total sleep in the 24 hours prior to signing on for duty for each flight;

[5] Actisoft version 2.0 was developed by Dr Alexander Smith, Sleep/Wake Research Centre, Massey University, New Zealand.

[6] Under ideal circumstances, baseline sleep should not be restricted by work or home demands, and should not include any recovery sleep resulting from prior accumulated sleep debt. In reality, estimates of baseline sleep were likely shorter than participants' true baseline sleep. However, it was considered an adequate estimate for evaluating changes in sleep across the ULR trip.

- Layover sleep per 24 hours was calculated for the first 24 hours of the layover (from duty end time) and the last 24 hours of the layover prior to signing on (the latter being the equivalent to pre-flight sleep for the inbound flight);
- Post-trip sleep: total sleep obtained at home in a 24-hour period from noon to noon (local time) on the 5 days post-trip, starting on the day of arrival in Johannesburg. Any sleep before noon was not included as post-trip sleep to enable comparisons between sleep on post-trip days and sleep on baseline days and evaluation of the recovery following the ULR trip.

For any 24-hour period that included one or more intervals scored as ‘Excluded’ (i.e. actigraph not worn during sleep) in the Actiware program, the entire 24-hour period was treated as missing data.

Actisoft was also used for calculating the following variables:

- Duration of time awake prior to signing on for duty
- Total in-flight sleep
- Sleep in the 24 hours prior to TOD
- Duration of time awake prior to TOD

The ‘duration of time awake’ variables were calculated as the number of minutes since final wakeup time of the preceding sleep period. For these calculations, sleep periods scored as ‘Excluded’ (i.e. missing actigraphy, but bed- and rise time recorded in diary) were included to prevent the duration of time awake being over-estimated.

The variables generated in Actisoft were subsequently imported into SPSS and SAS databases for statistical analysis. For sleep per 24 hours at home and on layover there was 5.1% missing data. There was no missing data for in-flight sleep.

2.4.9.3 Psychomotor Vigilance Task (PVT)

PVT data for each participant were downloaded from the Palm Centro and saved as a REACT PVT file, using the Palm PVT 3.0.0 software (Walter Reed Army Institute of Research, USA). In the REACT program (Ambulatory Monitoring Inc., USA), summary statistics were generated for each test, including response speed (1/reaction time x 1000), the slowest 10% of responses, the fastest 10% of responses, and lapses (responses exceeding 500ms in duration). These variables were exported to a MS Excel file, which was then imported into SPSS and SAS databases for statistical analysis.

The rate of missing data, in terms of tests not completed pre-flight (19.1%), at TOC (16.4%), and TOD (17.3%) was attributed to operational demands interfering with the study requirements. Initial inspection of the data raised concerns about the pre-flight test prior the outbound flight. A detailed evaluation of this data is included in Appendix H. After careful consideration, data from the outbound pre-flight test was deemed invalid. To enable comparisons between flight legs, both the outbound and inbound pre-flight tests were excluded from all data analyses.

In addition, 24.5% of TOC tests and 17.3% of TOD tests were excluded because these were completed outside the specified time windows. A detailed description of the exclusion criteria, and the number of tests included and excluded can also be found in Appendix H.

2.4.10 Statistical analyses

2.4.10.1 Descriptives

Descriptive statistics (means, medians, standard deviations, range, and proportions) were generated in SPSS, which included histograms, normal probability plots, detrended probability plots, and boxplots to check their distribution and identify any univariate outliers. Outliers, defined as 1.5 × interquartile range of the variable's distribution, were crosschecked and valid observations were retained in the dataset.

2.4.10.2 Non-parametric tests

Wilcoxon signed rank tests were used on non-normally distributed data to test for differences between repeated measurements on the same group of participants (Wilcoxon, 1945). This test is analogous to the parametric paired t-test.

Pearson's Chi-square tests (Pearson, 1900) were used to test whether two categorical variables were related, by comparing the observed frequencies in each category of a contingency table to frequencies expected by chance. Where expected frequencies in one of the cells was equal to or less than 5, the Fisher's exact test was used instead (Fisher, 1922).

2.4.10.3 Linear mixed models

The linear mixed model is an extension of the general linear model, which allows the modeling of both fixed and random effects, hence the name 'mixed'. Fixed effects are the traditional explanatory variables for which all levels about which inference is to be made, are known in the study. Random effects on the other hand represent a subset of levels randomly selected from a larger set of potentially infinite levels (Dickey, 2008; Littell, Milliken, Stroup, Woldfinger, & Schabenberger, 2006). In the present thesis research, participant ID was included as random effect to account for the between-subject variance in the data.

Whereas the general linear model (GLM) uses an estimation method (ordinary least squares) that requires complete data, the linear mixed model employs a likelihood-based estimation method, which uses all available data. A major advantage of this method is that it can handle unbalanced and/or missing data (Wolfinger & Chang, 1998).

Linear mixed modeling also enables the modeling of variances and covariances so that observations are allowed to be correlated, and have non-constant variance. This is particularly useful for repeated measures study designs, as used in this thesis research, because a) measures on the same individual are positively correlated because they share common contributions from that individual, and b) measures on the same individual close in time are often more highly correlated than measures further apart in time. The variances and co-variances are expected to exhibit a structure matching one of those available in the modeling procedure (Ramon C. Littell, Jane Pendergast, & Ranjini Natarajan, 2000). To select the best covariance structure between repeated measurements, each model was first run with a general covariance structure (Unstructured) that makes no assumptions regarding equal variances or co-variances. However, the computation of such a model can be problematic, as it requires the estimation of a much larger number of variance-covariance parameters compared to other structures (Littell, Henry, & Ammerman, 1998). If the unstructured option would run, the correlation matrix was assessed to determine appropriate covariance structures. These structures were then applied and compared to decide which provided the best fit. The Bayesian Information Criteria (BIC) was used for this purpose as it is considered the most conservative option by charging a heavier penalty for a larger number of parameters estimated. In SAS software version 9.3 and 9.4, a smaller value indicates a better fit. In those instances where the unstructured option could not be calculated, the theoretically suitable covariance structures were applied and compared (Littell et al., 2006; R. C. Littell, J. Pendergast, & R. Natarajan, 2000). In the present study, PVT tests and subjective ratings were not equally spaced in time. Therefore, the only appropriate covariance structures considered were Compound Symmetry and First-Order Ante-dependence. The Compound Symmetry structure specifies a constant variance between any two observations from the same participant, whereas the First-Order Ante-dependence structure assumes that the variance between pairs of observations changes over time (Littell et al., 2006).

The Kenward-Roger adjustment was applied for computing the degrees of freedom, which is recommended for linear mixed models with repeated measures involving smaller samples, and/or where data are unbalanced, in order to avoid inflation of Type I error rates (Guerin & Stroup, 2000; Kenward & Roger, 1997).

The specific model structures used for analyses are reported in the Results sections of Chapters 3 and 4.

For each model, collinearity between pairs of fixed effects was checked by computing the correlation, condition index, and proportion of variance values. Where the correlation was above 0.7, and/or the condition index higher than 30, coupled with a proportion of variance value higher than 0.5 for at least two fixed effects in the model, the variable with the highest variance proportion was removed from the model (Tabachnick & Fidell, 2013).

The linear mixed model assumes that the expected relationship between the outcome variable and predictors are linear. It is also assumes that the residual distribution is normal with a constant variance (Littell et al., 2006). Model assumptions were checked for each model. Normality of the studentized residual distribution was checked with the Shapiro-Wilk statistic or Kolmogorov-Smirnov statistic, in conjunction with visual inspection of the histogram, boxplot, and quantile-quantile plot. The Levene's test, in conjunction with the residual versus predicted mean plot, was used to check residual variance. For models with residuals exhibiting a non-constant variance, a more conservative alpha level of 0.01 was adopted. Where outlying residual values were identified, the model was re-run without the outlier(s). If removing the outlier(s) altered the findings of the model, then the reported results exclude the outlier(s). However, if the outcome of the model did not alter when outliers were removed, then the results reported are those including the outlier(s). Information about the presence and/or exclusion of outliers is included in the results (Tabachnick & Fidell, 2013).

Where main effects were statistically significant, post hoc *t* tests were used to make pairwise comparisons between levels of the significant effect(s). Where interactions were significant, simple effects analyses were undertaken to assess the effect of a fixed effect at individual levels of the other fixed effect (Littell et al., 2006).

Since multiple pairwise comparisons increase the Type I error rate, or the probability of finding an effect that in fact does not exist, the significance level for post hoc t tests was adjusted. The Bonferroni correction (Dunn, 1961), which distributes the significance alpha level of 0.05 across all the pairwise tests, was used for post hoc pairwise comparisons arising from mixed model ANOVAs and ANCOVAs. However, for mixed model repeated measures ANOVAs, which typically involved a greater number of post hoc pairwise comparisons being made, Holm's sequentially rejective procedure was employed, which adjusts the level of significance relative to the number of comparisons being made. This approach is considered less conservative than the Bonferroni method, thus reducing Type II errors, or the probability of rejecting an existing effect (Aickin & Gensler, 1996).

2.4.10.4 Polynomial models

Because previous studies have shown a curve-linear relationship between workload and fatigue-related performance impairment (Gaillard, 2001; Lysaght et al., 1989), the relationship between mean raw TLX score as a predictor and each of the outcome measures (KSS, SP, PVT performance) was evaluated before embarking on subsequent linear mixed models.

To assess non-linearity between mean raw TLX scores as a fixed effect and each of the dependent variables, hierarchical polynomial regression models were fitted which included a linear, quadric, and cubic term of the mean raw TLX score (Montgomery, Peck, & Vining, 2012). Type I (sequential) tests of fixed effects were produced to evaluate whether the quadratic and/or cubic term improved the overall model fit. A non-significant effect for the quadratic and/or cubic term in the Type 1 fixed effects was used as evidence that the relationship with the dependent variable was linear (SAS Institute Inc, 2015).

2.4.10.5 Local effect sizes

In addition to null hypothesis significance testing for determining the presence of any statistically significant effects, effect sizes provide a measure of practical significance (Nakagawa & Cuthill, 2007). An effect size measures the strength of an association between the outcome variable and predictor variable, and reflects the proportion of the variance accounted for by the model, i.e. explained variance (R^2), that can be attributed to the predictor variables (Cohen, 1988; Snijders & Bosker, 1994). In multiple regression, the effect of an individual variable on the response variable, or local effect size, is quantified by the squared semi-partial correlation coefficient, obtained by holding the influence of additional predictor variables constant (Peugh, 2010). This is however problematic in linear mixed models, which have several variance components for the fixed and random effects. The addition of a predictor variable to a linear mixed model can potentially increase, rather than decrease one or more variance components, for example when this variable explains primarily within-subject variability and very little between-subject variability (Snijders & Bosker, 1994).

This problem can be circumvented by using a recently reported approach for calculating local effect sizes (Cohen's f^2) of fixed effects in linear mixed regression models (Selya, Rose, Dierker, Hedeker, & Mermelstein, 2012).

This approach was utilized in the present study for quantifying the independent contributions of perceived workload, sleep history, and flight sector on subjective sleepiness, fatigue, and PVT performance at top of descent.

It involves running different versions of the mixed regression model, including a full model that contains all fixed effects (predictor variables), a null model that contains no fixed effects, as well as models where only one of the fixed effects has been excluded.

The full model, including all fixed effects and participant ID as random effect, was run first to obtain values for the random effect covariance parameters. These values were then used to fix the random effect variance in the remaining models. Because the random effect variance was held fixed, the change in variance after removing a fixed effect was therefore attributed to the fixed effect only.

The residual variance (*V*) values from the full model, null model and each of the models excluding one of the fixed effects were then used to calculate the R^2 value for each model. For example, for the model that excluded workload (mean raw TLX score):

$$R^2{}_{model\ minus\ workload} = \frac{V_{null\ model} - V_{model\ minus\ workload}}{V_{null\ model}}$$

R^2 values were then used to calculate Cohen's f^2 for each fixed effect. For example, for workload:

$$f^2_{workload} = \frac{R^2_{full\ model} - R^2_{model\ minus\ workload}}{1 - R^2_{full\ model}}$$

All models were specified using the Maximum Likelihood (ML) estimation method, rather than the default Restricted Maximum Likelihood (REML) method, which is recommended when models with different fixed effects are compared (Snijders & Bosker, 2012).

Effect sizes were classified as small (f^2=.02), medium (f^2=.15) or large (f^2=.35) according to Cohen's guidelines for linear regression analysis (Cohen, 1988).

2.5 Focus group study (Study 2)

Focus group discussions were considered the best choice for addressing the second research question, as group discussions can generate a large volume of data and identify a greater variety of views, opinions and experiences in comparison to individual interviews (Hennink, 2007). Furthermore, group discussions provide data that is enriched through the process of group interaction, not attainable by interviews with individuals or quantitative methods such as surveys (Braun & Clarke, 2013).

The discussions were semi-structured to a) enable comparisons to be made across the entire dataset, and b) allow participants raise other factors that were not anticipated.

2.5.1 Ethical considerations

The study was reviewed and approved by the Massey University Human Ethics Committee: Southern A (Application 13/45; Appendix I). Subsequent minor amendments were made as follows.

Following the initial application, a research assistant was identified at SAA and his contact details were added to the participant information sheet.

Due to their irregular work patterns, returning a signed 'authority for the release of transcript' form to the research assistant at SAA proved to be very difficult for the participants. Therefore, an email format was used instead.

Several aspects of the study design required careful consideration.

Firstly, for logistical reasons the focus group discussions were to be held at South African Airways. However, participants could feel uncomfortable sharing negative work-related experiences, or might reveal issues with the potential for risk of harm, e.g. regarding unsafe work practice, high levels of fatigue or negative comments concerning their employer. Maintaining privacy throughout the discussion was of high importance and therefore a room was selected that was sufficiently private.

Secondly, a research assistant was sought at SAA to help with the recruitment and facilitation of the focus groups. Care was taken that the research assistant was a fellow cabin crewmember who did not hold a position of authority, to minimize any influence on the group dynamics (Hennink, 2007). The research assistant (MM) was asked to sign a confidentiality agreement (Appendix J) prior to start of recruitment.

Thirdly, participants were offered a gift voucher (ZAR500, which equals NZ$64.96 at an exchange rate of 0.13) as remuneration for their time to review their contribution in the transcript and for foregoing allowances associated with flying duty. A concern was raised by the research assistant (MM) that the value of the gift voucher would be the sole motivator to volunteer for the study. However, we argued that even though participation was during paid ground-based duty, participants would forego any allowances associated with international flying. In addition, participants were asked to give their own time for checking their transcribed contribution, and subsequently the draft report. To minimize the risk of coercion, gift vouchers were handed out at the start of the focus group discussion and participants were informed that they were free to leave the group at any time if they no longer wished to partake.

Participation was voluntary and informed, written consent was obtained prior to the start of each focus group discussion.

2.5.2 Participants and recruitment

The aim was to conduct at least three focus groups, with 8-10 participants in each group. The average recommended focus group size is eight, "small enough for everyone to have an opportunity to share insights and yet large enough to provide diversity of perceptions". If no new issues are raised in the 3rd focus group, then additional focus groups are not expected to generate new information or provide additional understanding of the research question (Krueger & Casey, 2000).

All cabin crew who had flown the Johannesburg-New York ULR route at least once were invited to take part, by means of advertisement via the company communication channels (Appendix K). The total pool of potential participants was around 1500, since SAA has been flying this daily route since May 2011, with 14 crewmembers on each flight. Recruitment began in November 2013 and closed on 15 December 2013 to allow rostering of participants to ground-based duty during one of two days in February 2014 during which the focus group interviews would take place. Interested crewmembers could contact the research team by email or by phone and were given an introductory letter containing detailed information on the study (Appendix L) and a consent form (Appendix M). Recruitment was stopped once the required number of cabin crew had agreed to participate.

2.5.3 Procedure

Participating cabin crew were rostered on ground-based duty to enable attendance at one of three 2-hour focus group discussions scheduled across two consecutive days (20-21 February 2014). The focus group discussions were held at SAA, facilitated by the researcher and a research assistant (MM[7]).

Prior to the start of the focus group discussion, participants were given the opportunity to ask any questions and were asked to provide written consent. They were also asked to

[7] MM=Masilo Matseke

complete a brief demographic questionnaire (Appendix N), to collect information on age, gender, and work experience. Gift vouchers were also handed out at this time.

The researcher led the discussion while the research assistant took detailed notes. An interview script (Appendix O) was used which included a brief introduction to reiterate the purpose of the study and the participants' right to withdraw from the study at any time. Participants were also given the opportunity to ask any further questions before the audio recording was started. The discussion was preceded by a quick warm-up question in which each of the participants were invited to introduce him/herself. Eight key questions were used to guide the discussion and these were displayed as visual prompts on a poster during the discussion (Appendix P). All participants were encouraged to contribute to the each of the questions during the group discussion.

Each focus group discussion was recorded digitally and ranged in duration from 96 to 133 minutes. A Sleep/Wake Research Centre staff member of South African nationality with extensive transcription experience transcribed the audio recordings verbatim, using the Express Scribe software (NCH Software Pty Ltd, Canberra, Australia). The transcripts were then crosschecked against the audio recordings by the researcher and corrections were made as required. The transcripts were then anonymized and participants were given the opportunity to check, edit or withdraw their contribution and their approval was sought in writing to have their data included in the analysis (Appendix Q).

2.5.4 Data analysis

Thematic analysis (TA) was used to identify patterns in participants' views and opinions across the dataset. This was undertaken using a 6-phase iterative process described by Braun and Clarke (Braun & Clarke, 2006). Within TA, there are different approaches to coding and identifying patterns. For example, in Theoretical TA, the coding and theme development are constructed from a pre-existing theory and/or concepts. In the present study however, 'experiential' TA was used, focusing on the participants' standpoint and experiences. To stay close to the participants' accounts, the coding process was primarily semantic, or data-derived (Braun & Clarke, 2013). The six analysis phases were as follows.

2.5.4.1 Familiarisation with the data

Transcripts were read and checked several times against the original audio recordings and reference was made to the notes taken by the research assistant during the interviews. Initial observations made during this phase were recorded in a memo.

2.5.4.2 Generating initial codes

Complete coding was undertaken in NVivo 10 (QSR International, Melbourne, Australia), a software application for qualitative data management and analysis. Each section of text was assigned one or more codes based on the contents of the data. Full and equal attention was given to each data item. Using an iterative coding process, new codes were created while working systematically through each transcript. Once the initial coding was completed, each transcript was reviewed against the full list of codes and data items were re-coded as required.

2.5.4.3 Collation of codes into candidate themes

Identification of themes was also undertaken in NVivo 10. Codes were in first instance sorted by similarity in meaning and then grouped into candidate (sub-) themes (e.g. 'service to passengers), which in turn were grouped in broader themes (e.g. 'workload'). An initial thematic map, visualizing the candidate themes, sub-themes and their relationships was created to assist with this process (Appendix R, Figure R-1). With the view to producing an analysis that is practical and solution-focused, these candidate themes and sub-themes were categorized into the following sections: 1) the causes of fatigue, 2) the consequences of fatigue, 3) self-management of fatigue, 4) suggestions for change to improve cabin crew fatigue, 5) company factors and other work-related factors.

2.5.4.4 Reviewing of themes

Candidate themes were initially reviewed and discussed with a member of the research team (LS) and an expert qualitative researcher (AL)[8]. Candidate themes and sub-themes were categorized into broader themes, re-arranged, or discarded to capture the coded data adequately. A second review was subsequently undertaken with the research team (LS, PG), to further refine themes and sub-themes.

2.5.4.5 Defining/naming of themes

During the review process, theme names and sub-theme names were evaluated and changed where necessary, to better reflect the essence of the theme/sub-theme. Finalized themes and sub-themes for each section are illustrated in Figures S1-5 in Appendix S.

2.5.4.6 Analysis and interpretation of patterns

For the final phase of the data analysis, themes and sub-themes (i.e. patterns in the data) were illustrated with data extracts and their relevance discussed in the context of the research questions and existing literature. Each data extract includes a reference to its source, as follows: "(group number, ID)". Where surplus or irrelevant information was excluded from the quoted comment, the exclusion is denoted by […]. Pauses are denoted by '…' and words that were spoken with strong emphasis are <u>underlined</u>. When it was not possible to distinguish what was being said due to multiple participants speaking at the same time, this is denoted by [cross talk]. However, when it was clear that group members agreed with someone's comment, this is denoted by [agreement from the group]. There was also intermittent aircraft noise that

[8] LS= Assoc. Prof Leigh Signal; AL= Prof Antonia Lyons; PG=Prof Philippa Gander

rendered some of the comments inaudible. The room in which the focus group discussions took place was not air-conditioned and windows were open to ensure the comfort of participants. Inaudible sections were denoted as [inaudible].

2.5.4.7 Verification

Since Braun & Clarke's method of coding is an active and reflexive process, it inevitably bears the mark of the researcher. With no one 'accurate' way to code data, the logic behind inter-rater reliability thus disappears (Braun & Clarke, 2013). Instead, to obtain a degree of verification, member reflections (Tracy, 2010) were sought by giving participants the opportunity to comment on the draft report to management at SAA. Received comments were anonymized and are included in Appendix T.

CHAPTER 3 MONITORING AND MANAGING CABIN CREW SLEEP AND FATIGUE DURING AN ULTRA-LONG RANGE TRIP

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This manuscript was prepared by the doctoral candidate (see Appendix X) and has been published in Aerospace Medicine and Human Performance Vol 86, No 8, 2015[9].

3.1 Abstract

Background: The aims of this study were to monitor cabin crew fatigue, sleep and performance on an ultra-long range (ULR) trip and to evaluate the appropriateness of applying data collection methods developed for flight crew to cabin crew operations, under a fatigue risk management system (FRMS).

Methods: Fifty-five cabin crew (29 women; mean age 36.5 years; 25 men; mean age 36.6 years; one missing data) completed a sleep/duty diary and wore an actigraph prior to, throughout, and following the ULR trip (outbound flight ULR; mean layover duration=52.6 hours; inbound flight long range). Across each flight, crewmembers rated their fatigue (Samn-Perelli Crew Status Check) and sleepiness (Karolinska Sleepiness Scale) and completed a 5-minute Psychomotor Vigilance Task (PVT) at key times.

[9] Approval to include the accepted version of the manuscript as a chapter in this thesis was granted by the Managing Editor, Aerospace Medicine and Human Performance (P. Day, personal communication, 21 June 2018).

Results: Of crewmembers approached, 73% (n=134) agreed to participate and 41% (n=55) provided data of suitable quality for analysis. In the 24 hours before departure, sleep averaged 7.0 hours and 40% took a pre-flight nap. All crewmembers slept in flight (mean total sleep time=3.6 hours outbound, 2.9 hours inbound). Sleepiness and fatigue were lower, and performance better, on the longer outbound flight than on the inbound flight. Post-trip, crewmembers slept more on day 1 (mean=7.9 hours) compared to baseline days, but there was no difference from day 2 onwards.

Discussion: The present study demonstrates that cabin crew fatigue can be managed effectively on a ULR flight and that FRMS data collection is feasible for cabin crew, but operational differences between cabin crew and flight crew need to be considered.

Key words: Actigraphy, Karolinska Sleepiness Scale, Samn-Perelli Crew Status Check, Psycho-motor Vigilance Test, Fatigue Risk Management System

3.2 Background

Ultra-long range (ULR) trips are flight operations between a specific city pair in which at least one of the sectors regularly exceeds 16 hours planned flight time. The duty periods on these flights range between 18 and 22 hours (Flight Safety Foundation, 2005b). Such flights present a challenge for airlines and regulators, as they can potentially increase fatigue-related operational risk, particularly during the later stages of the flight, if they lead to restricted sleep, extended periods of wakefulness, and/or high operational demands at sub-optimal times in the circadian body clock cycle. They may also require additional time for recovery sleep during the layover or on return home following a ULR trip.

To manage the fatigue risk associated with ULR trips, airlines are usually required to put in place a Fatigue Risk Management System (FRMS). Current ULR scheduling for cabin crew is predominantly based on flight crew data and to date, studies have focused solely on data collection and the effectiveness of FRMS for flight crew. Hence little is known about how these processes work for cabin crew.

As for flight crew, the main fatigue mitigation strategy on ULR flights is to provide cabin crew with scheduled in-flight rest breaks for sleep in crew rest facilities, which requires additional crewmembers on board. The effectiveness of in-flight rest breaks as a mitigation for fatigue depends on the amount and quality of sleep that crewmembers are able to obtain in flight (Signal et al., 2005). This is not only dependent on flight duration, but also on other operational factors, including local time of departure and the timing and duration of in-flight rest breaks, which will influence how well crewmembers are able to sleep at various times during the flight (Gander, Mulrine, van den Berg, Smith, Signal, et al., 2014; Gander, Signal, et al., 2013; Signal, Gander, et al., 2013). Compared to flight crew, cabin crew have less time available for in-flight rest due to the requirement for all cabin crew to be awake for meal services. In addition, regulatory requirements for on-board rest facilities are often less rigorous for cabin crew than for flight crew (Banks et al., 2009).

Additional mitigations include providing crewmembers with protected time free of duty before, during (i.e. on layover) and after the ULR trip, to assist with preparation for the trip and subsequent recovery. Compared to flight crew, a larger proportion of cabin crew are female, and may have greater domestic responsibilities compared to their male counterparts. This may in turn impact on their sleep at home. The rate of recovery post-trip will also vary with the degree of circadian misalignment resulting from the trip and may be slower if greater sleep loss was accumulated during the trip.

The amount and quality of sleep crewmembers are able to obtain during the layover, and the extent to which they adapt to the layover time zone, is influenced by layover duration and timing, as well the number of time zones crossed and flight direction. Previous research has shown that after a westward transmeridian flight, which effectively lengthens the day, circadian adaptation tends to be faster compared to after an eastward transmeridian flight (Gander, Gregory, et al., 1998). Although the amount of circadian adaptation during a 2-day layover is not well documented, this will be influenced not only by the degree of light exposure, but also by social activities (Czeisler & Buxton, 2017). While retaining a home-based sleep pattern has been shown to reduce sleepiness during a 2-day layover (Lowden & Åkerstedt, 1998a), crew often time at least some of their layover sleep to occur during the local night (Lowden & Åkerstedt, 1999).

As a further mitigation, crew receive fatigue management training (Flight Safety Foundation, 2005b). Presently, information contained in such education material is based entirely on flight crew experience, due to the lack of data available for cabin crew.

The aim of this study was to evaluate the effectiveness of fatigue management for cabin crew on a westward outbound Johannesburg-New York ULR trip, by monitoring their sleep, sleepiness, fatigue, and performance before, during, and after this trip. A secondary aim was to determine the appropriateness of data collection methods and measures for cabin crew.

3.3 Methods

3.3.1 Subjects

The study protocol was approved by the Massey University Human Ethics Committee (application 11/74). Each crewmember provided written informed consent before participating. Participation was voluntary and confidentiality was strictly maintained.

Fifty-five crewmembers participated in the study. Demographics were available for 54 crewmembers (29 women, mean age 36.5 years, 25 men, mean age 36.6 years) and are summarized in Table 3-1.

3.3.2 Materials

At the start of their involvement in the study, crewmembers completed a pre-study questionnaire which was included in the sleep/duty diary. The questionnaire, which was adapted from one used for flight crew in multiple previous airline studies (Gander, Signal, et al., 2013; Signal, Gander, et al., 2013), included items on cabin crew position, flying experience, age, gender, usual sleep at home on days off duty, usual sleep in on board crew rest facilities, and in-flight fatigue.

Crewmembers completed a sleep/duty diary throughout the study. This included a look-back report to record duty periods in the week leading up to the start of participation, and 24-hour timelines for recording sleep and duty information. For each study flight leg, additional pages were included to collect operational information including scheduled and actual duty start and end time, crew position for the flight (Galley or Aisle; Premium or Economy), planned rest breaks for the flight, and how the crewmember usually manages fatigue on this flight. There was also space for recording fatigue and sleepiness at specified times.

Crewmembers wore an actigraph (Spectrum from Philips Respironics, Bend, Oregon, USA) throughout their participation in the study. Actigraphy is a validated, well recognized, widely used method for recording sleep in a range of different populations (Ancoli-Israel et al., 2003) and has been validated for flight crew (Signal et al., 2005). The device is the size of a wrist watch, with a functioning watch face, and is worn on the non-dominant wrist. Crewmembers were asked to press a button ("event marker") on the actigraph to indicate when they began and finished trying to sleep. Data were recorded in 1-minute epochs and subsequently downloaded to a computer for analysis. Actigraphy data were analyzed using the manufacturer's software (Actiware® version 5.71.0, Philips Respironics, Bend, Oregon, USA) at the medium sensitivity setting, in conjunction with the sleep time information from the sleep/duty diary.

Crewmembers were asked to rate their fatigue before and after each sleep episode and at different times in flight on the Samn-Perelli Crew Status Check (SP), on a scale from 1= 'fully alert, wide awake' to 7= 'completely exhausted, unable to function effectively' (Samn & Perelli, 1982). At the same time, sleepiness was rated on the Karolinska Sleepiness Scale (KSS), on a scale from 1= 'extremely alert' to 9= 'extremely sleepy, fighting sleep' (Åkerstedt & Gillberg, 1990; Gillberg et al., 1994; Härmä et al., 2002). Both scales have been extensively used for measuring subjective fatigue and sleepiness. The SP was developed for use with military airlift flight crew (Samn & Perelli, 1982), has been widely used in studies with commercial flight crew (Gander, van den Berg, et al., 2011; Pascoe et al., 1995) and has been validated in laboratory studies using forced internal desynchrony protocols (Ferguson et al., 2012). The KSS has been used to measure subjective sleepiness in both laboratory (Åkerstedt & Gillberg, 1990) and field studies (Gillberg et al., 1994; Härmä et al., 2002). After each sleep episode, crewmembers were also asked to rate their sleep quality on a scale from 1= 'extremely good' to 7= 'extremely poor', which has been used in previous airline studies (Gander, van den Berg, et al., 2011; Signal, Mulrine, et al., 2013). At the end of each flight, crewmembers were asked to rate their workload on the raw NASA Task Load Index. These data are not included in the present analyses.

Performance was measured using a validated, 5-minute version of the Psychomotor Vigilance Task (PVT) (Roach et al., 2006) (PalmPVT, Walter Reed Army Institute of Research) on a Palm Centro Smartphone (Palm, Inc., Sunnyvale, California, USA). The inter-stimulus interval varied randomly between 2-10 seconds. Crewmembers were required to attend to a display on the screen and respond as quickly as possible by pushing a button as soon as a 'bulls-eye' symbol appeared with numbers in the centre that represented response time counting in milliseconds. The crewmember received immediate feedback on their reaction time each time the response button was pushed.

3.3.3 Procedure

Information on the study was initially advertised via the airline company's communication channels. All cabin crew scheduled on a Johannesburg-New York-Johannesburg trip during the study period (27 August 2012 to 24 June 2013) were eligible to participate. For each scheduled trip, up to seven of the 14 crewmembers were contacted by a member of the research team and invited to participate. Since the aim was to recruit data from at least 50 cabin crew for this study, it was considered important to sample a range of flights in case conditions varied widely from one flight to the next or in the event of peculiarities on one particular flight (e.g. delays, turbulence, medical event).

At least 4 days before the study trip, participating crewmembers received an actigraph, a Palm Centro Smartphone and a sleep/duty diary. Crewmembers were asked to wear the actigraph and complete the sleep/duty diary from 3 days prior to departure, throughout the entire ULR trip (on both flight legs and layover), and until 5 days after the ULR trip.

The company recommended that on the outbound ULR flight, the time available for rest in the bunk (between the two meal services) should be split into four rest breaks. No recommendations regarding rest break pattern were provided for the shorter, non-ULR inbound flight. The 14 cabin crew (including one senior purser and two pursers) that operate the A340-600 aircraft on the Johannesburg-New York route, work as A and B crews who alternate their periods of duty and rest, with the B crew taking the first and third break on the outbound flight. In addition to the bunk rests, a 40-minute seat rest can be taken on the outbound flight if needed, in one of two allocated seats in the cabin.

The crew rest facilities for cabin crew are located below the main cabin at the rear of the aircraft. Of the seven horizontal bunks, six are positioned longitudinally, with three upper and three lower bunks. The seventh bunk is transversely positioned, above a storage unit. The bunks, which are separated from each other by a hard panel, each have a curtain which can be closed for privacy. Blankets and pillows are provided and the rest area is temperature and humidity controlled.

Cabin crewmembers are required to attend fatigue training before being able to fly this ULR route. As part of this training, recommendations were made to crewmembers to arrive for duty with no sleep debt by having two good nights of sleep before the start of duty. The benefits of pre-flight napping were also explained. In addition, crewmembers were advised to stay on domicile time during the layover to assist with recovery post-trip.

Crewmembers were rostered to be free of duty during the 48 hours prior to their ULR trip and the entire crew was on standby the evening before their scheduled departure. Following the ULR trip, crewmembers were provided with four local nights at home before their next duty period.

A total of 36 return trips were studied between 27th August 2012 and 24th June 2013, with 33 having data included in the study. Daylight saving time in New York began on March 10th 2013, with 19 return trips completed prior to this and 14 return trips following this date (resulting either in a 7-hr or 6-hr time zone change). Details of flight departure and arrival times and duration of flights (time between blocks-off and blocks-on) and layovers are provided in Table 3-2.

The westward outbound flights were scheduled to depart Johannesburg at 20:40 local time, with a local arrival time of 06:40 in New York (12:40 Johannesburg time). Following a layover of approximately 48 hours, the eastward inbound flight was scheduled to depart

New York at 11:15 local time (17:15 Johannesburg time), with a local arrival time of 08:00 (01:00 New York time).

On the day of each flight, crewmembers were asked to rate their fatigue and sleepiness and complete a PVT: 1) pre-flight, after signing on for duty, 2) around top of climb (TOC; once the seatbelt sign was turned off and within 90 minutes after take-off), 3) around top of descent (TOD; at the end of the last meal service and within 90 minutes before landing), and 4) after landing.

Sleep/duty diaries were available for all crewmembers, but four had incomplete sections and others had occasional responses missing. All data entries were cross-checked by a second independent researcher and discrepancies (0.1%) were reviewed and rectified. Data were also screened for outliers, which were cross-checked against the sleep/duty diary data.

For fatigue and sleepiness ratings after night-time sleep (i.e. sleep occurring during the local night), where night-time sleep was split, only ratings after the final sleep episode were included.

Actigraphy recordings were available for all 55 crewmembers, however some were incomplete. Eleven crewmembers had a duty period on post-trip day 5 and were therefore excluded from analyses for this day.

Actigraphy records were scored using Actiware® software. To assess the reliability of the manual identification of rest intervals, 20% of files were double-scored by a second independent trained researcher. Discrepancies of more than 15 minutes occurred in 10.9% of rest interval start times and 7.8% of rest interval end times. These discrepancies were reviewed and any errors were corrected. An overall agreement (15 minutes or less difference between scorers) of 90.7% was achieved. Total sleep time per sleep period (TST) was calculated as the number of minutes of sleep from sleep onset (the first 10 consecutive minutes scored as sleep by the software algorithm) until final wake-up (Signal et al., 2005).

A custom-built program was used calculate the total amount of sleep across specific 24-hour intervals, as follows.

- Baseline sleep: total sleep per 24 hours from 72-24 hours preceding noon on the day of departure. Data for baseline day 1 included eleven crewmembers who were on duty and four crewmembers who were on standby, while for Baseline day 2 one crewmember was on duty and one crewmember was on standby.
- Pre-flight sleep: total sleep in the 24 hours prior to signing on for duty for each flight.
- Layover sleep per 24 hours was calculated for the first 24 hours of the layover and the last 24 hours of the layover (the latter being the equivalent to pre-flight sleep for the inbound flight).
- Post-trip sleep: total sleep obtained at home in a 24-hour period from noon to noon (local time) on the 5 days post-trip, starting on the day of arrival in Johannesburg. Any sleep before noon was not included as post-trip sleep to enable comparisons between sleep on post-trip days and sleep on baseline days and evaluation of the recovery following the ULR trip (eleven crewmembers took post-flight naps beginning before noon).

On average, crewmembers completed five PVT tests (range 3-6). Some data were excluded from analyses due to the test not being undertaken within the required timeframe, and an additional six crewmembers had no valid PVT data (e.g. due to incorrect settings, wrong response button pressed, or malfunctioning equipment).

PVT data for each crewmember were downloaded and summary statistics were generated for each test using the REACT program (Ambulatory Monitoring Inc., USA). Subsequent analyses were carried out in SPSS (version 21.0, IBM SPSS Statistics for Windows, Armonk, NY, USA) and SAS (version 9.3, SAS Institute Inc., Cary, NC, USA). Results for PVT response speed (1/reaction time x 1000), fastest 10% of responses, slowest 10% of responses and lapses (response times exceeding 500 ms in duration) are reported here.

3.3.4 Statistical analysis

Linear mixed modeling was undertaken using SAS 9.3. For the between-subject mixed models, subject ID number was included as random effect to account for individual differences, with 'variance components' applied as covariance structure. The Kenward-Roger adjustment was applied to the degrees of freedom estimation (Littell et al., 2006). For each model, the assumptions of normality, linearity, and constant variance were checked visually and the distribution of the residuals were tested with the Shapiro-Wilk test of normality and Levene's test for constant variance (Tabachnick & Fidell, 2000). Where outlying residual values were identified, the model was re-run without the outlier(s). If removing the outlier(s) changed the findings of the model, then the reported results exclude the outlier(s). However, if the outcome of the model did not change with the outlier(s) removed, then the results reported are those including the outlier(s).

For the mixed design ANOVAs for repeated measures, where possible, each model was first run with a general covariance structure (unstructured) and the correlation matrix assessed to determine appropriate covariance structures. In the present study, subjective ratings and PVT tests were not equally spaced in time therefore the only appropriate covariance structures considered were compound symmetry and first-order ante-dependence. The Bayesian Information Criteria (BIC) was used to determine which covariance structure provided the best model fit. Only compound symmetry was used in the final models.

Post hoc tests were used to investigate comparisons of interest where main and interaction effects were statistically significant in the mixed design ANOVAs for repeated measures. Holm's sequentially rejective procedure was employed to adjust the level of significance (Aickin & Gensler, 1996).

Bonferroni adjusted p-values were calculated for post hoc tests for significant interactions and fixed effects with more than two levels of comparisons in the mixed design ANOVAs and ANCOVAs.

3.4 Results

A total of 183 cabin crew were approached to participate in the study. Of these, 134 (73%) agreed to participate. Of those who agreed to participate, 28 (21%) did not undertake data collection for various reasons (e.g. change of mind, sick leave, forgot to collect study pack) and 25 (19%) stopped collecting data during their participation. Eighty-one (60% of those who agreed to participate; 44% of those invited to participate) completed data collection. Of these, eleven datasets (14%) were excluded due to equipment failure and 15 datasets (19%) were excluded due to too much missing actigraphy data. Datasets from 55 cabin crew (41% of those who agreed to participate; 30% of those invited to participate) were of sufficient quality to be included in the final analyses.

Table 3-1 Crewmember Demographics

	Cabin crew [a] Median (range)	Pursers [b] Median (range)	Senior Pursers [c] Median (range)	All crew Median (range)
Age (years)	35 (23-60) [d e]	41 (36-56)	43.5 (40-54)	36 (23-60) [e]
Work experience (years)	11.9 (1-38) [d e]	14.8 (13-21) [e]	18.5 (17-23)	12.5 (1-38) [d e]
Average work hours per month	110 (55-150)	120 (90-165)	120 (80-120) [d]	110 (55-165)
Expected work hours during the month of the study flight	100 (60-150)	100 (90-165) [e]	110 (75-120)	100 (60-165)
Long range experience (years)	10.5 (1-19) [d]	14.7 (12-21) [e]	16.7 (0.6-18) [d]	12.0 (0.6-21) [d]
Total number of crew	43	7	4	54

Medians and range are reported for both non-normally and normally distributed data; [a] Crewmembers who do not have management responsibilities; [b] Cabin crew member with in-flight management responsibilities in a specific cabin class; [c] Cabin crew member with in-flight management responsibilities who has the overall responsibility for the aircraft cabin; [d] Data not normally distributed; [e] Includes 1 outlier.

Table 3-2 Flight Details

Study period		Mean	Median	Range	N
Outbound flight (JNB-JFK [b])					
	Departure time (UTC [c])	18:48	18:47	18:22-20:05	55
	Arrival time (UTC)	10:44	10:41	10:15-11:50	55
	Flight duration (hours ± SD)	15.9 ± 0.4	16.0	15.3-16.7	55
	Duty duration (hours ± SD)	18.9 ± 1.0	18.6	17.8-22.1	31
Layover					
	Duration (based on arrival and departure time, hours ± SD) [a]	52.6 ± 0.3	52.6	51.4-53.2	35
	Duration (based on duty end and start time, hours ± SD)[a]	49.3 ± 1.2	49.5	44.4-51.4	52
Inbound flight (JFK-JNB)					
	Departure time (UTC) [a]	15:20	15:15	15:05-15:47	52
	Arrival time (UTC) [a]	06:05	06:04	05:24-06:36	52
	Flight duration (hours ± SD)	14.7 ± 0.3	14.7	13.7-15.2	55
	Duty duration (hours ± SD)	18.2 ± 1.1	18.0	16.5-21.6	38

[a] Three crewmembers were excluded whose flight was delayed for 22 hours; [b] JNB=Johannesburg (UTC+2h); JFK=New York (UTC-5h; during daylight saving time -4h); [c] UTC=Coordinated Universal Time

Performance on the pre-flight PVT test prior to the outbound flight was much slower and included more lapses than at TOC or pre-flight prior to the inbound flight. The most likely explanation is that this was a result of distractions in the testing environment, so pre-flight tests were not included in subsequent analyses.

The overall pattern of cabin crews' sleep and work is shown in Figure 3-1.

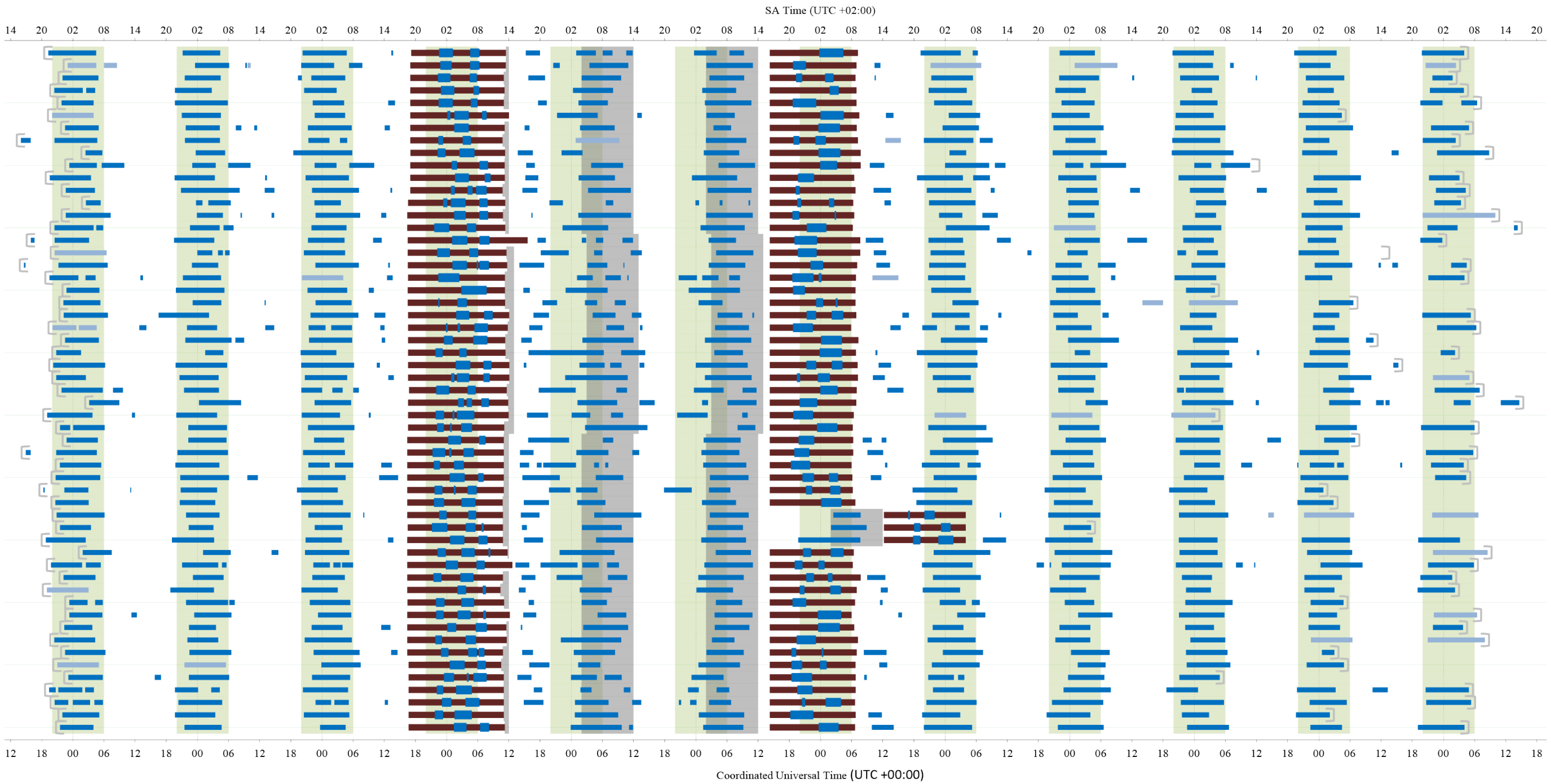

Figure 3-1 Pattern of sleep and work for each crewmember across the JNB-JFK-JNB trip

Blue bars = sleep periods (actigraphic); Light grey bars = sleep periods (based on diary) Brown bars = flight legs; Dark grey shading = local night; Light green shading = JNB night; Brackets=start-and end date of participation

The total amount of sleep obtained per 24 hours at home pre-trip, on layover and post-trip is shown in Figure 3-2. Descriptive statistics are presented in Appendix U, Table U-1.

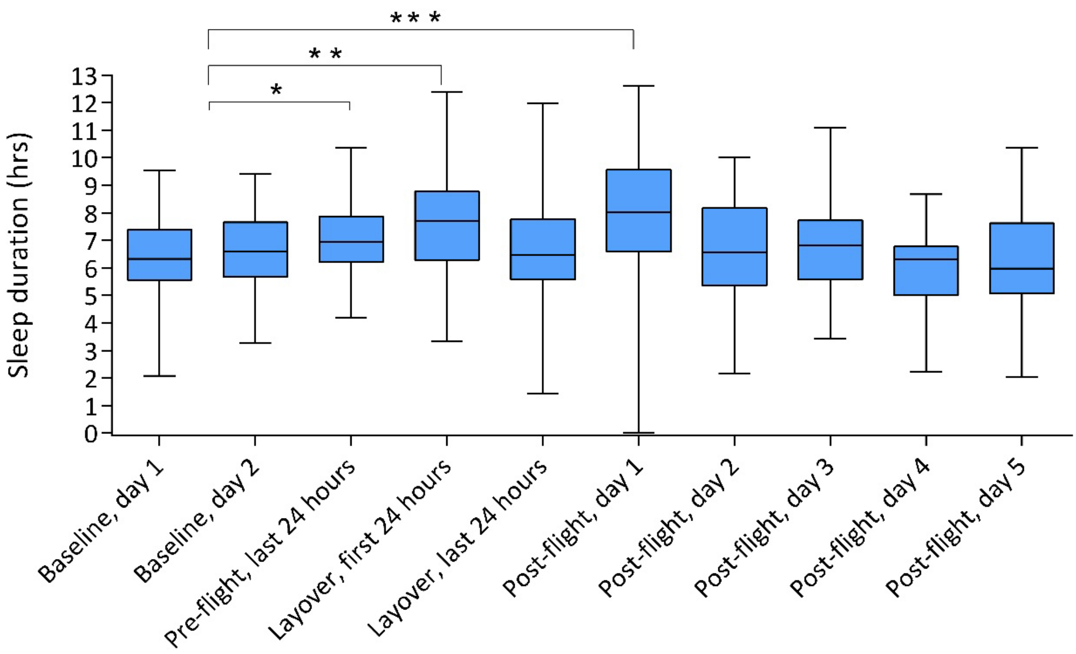

Figure 3-2 Total sleep (hours) per 24 h at home and on layover[10]

On baseline days, crewmembers obtained on average 6.5 hours sleep per 24 hours (range 2.1 - 9.5 hours). They obtained on average 33 minutes more sleep in the 24 hours before departure compared to baseline ($F(1, 106) = 6.80$, $P=0.01$). As illustrated in Figure 3-1, almost half of the crewmembers (22/55) had a pre-flight nap on the day of departure. More crewmembers (13/24) assigned the 2nd and 4th scheduled bunk rests (i.e. the A crew) took a pre-flight nap in comparison to crewmembers (7/29) who were given the 1st and 3rd scheduled bunk rests (the B crew) ($X^2(1) = 5.04$, $P=0.02$). Crewmembers who in the pre-

[10] In this plot, each boxplot displays the middle 50% of data as a grey box, with the median value indicated by the horizontal line inside the box. The whiskers represent the minimum and maximum values. Statistically significant post hoc pairwise comparisons (from three linear mixed models) are denoted by * for P <0.05, ** for P<0.01 and *** for P<.0001.

study questionnaire reported napping often or always at home on days off, were not more likely to take a pre-flight nap in comparison to crewmembers who reported to never, seldom or sometimes nap at home ($X^2(1) = 1.73$, $P=0.19$).

On the outbound flight, the usual pattern for in-flight rest was 3h-3h-2h-2h or 2h-2h-3h-3h with each crewmember scheduled for two rest breaks in the crew rest facility (i.e. bunk), except for two crewmembers who each had one 5-hour rest break in the bunk. On the shorter inbound flight, more than half of the crewmembers (32/55) had one single, 4-hour bunk rest break, occurring either in the first or second half of the flight. Three crewmembers followed a different in-flight rest pattern (2 hours-4 hours-2 hours), while the remainder had a rest break pattern similar to that employed on the outbound flight, with each crewmember scheduled for two 2-hour rest breaks.

On the outbound flight, an additional seat rest was taken by almost 50% of crewmembers. On the inbound flight, only four crewmembers took an additional seat rest, since on this flight leg, a seat for this purpose was not usually provided.

On each flight, all crewmembers attempted sleep during each scheduled bunk rest break and all crewmembers obtained some sleep during at least one of their breaks, averaging 216 minutes (range 98-303 minutes) on the outbound flight and 175 minutes (range 40-255 minutes) on the inbound flight.

A mixed model ANCOVA was run to determine whether flight leg (outbound/inbound) and crewmember age influenced the total amount of in-flight sleep, irrespective of scheduled bunk rest break pattern. Crewmembers obtained on average 41 minutes more sleep on the outbound flight than the inbound flight ($F(1, 53) = 25.89$, $P<0.001$) and age was not associated with the amount of sleep obtained in flight ($F(1, 52) = 0.26$, $P=0.61$). A further ANOVA showed that the total amount of in-flight sleep on the outbound flight did not differ between crew who had the 1st and 3rd break and crew who had the 2nd and 4th break ($F(1, 51) = 0.01$, $P=0.93$; mean estimated total sleep time of 216 and 215 minutes respectively).

To determine if the total amount of sleep on the inbound flight was affected by the number or timing of the rest breaks, comparisons were made between crewmembers who had the 1st and 3rd break, 2nd and 4th break, first single break and second single break. The distribution of total in-flight sleep for each of these break patterns is illustrated in Figure 3-3. The results from the mixed model ANOVA showed a significant difference between rest break patterns ($F(3, 48) = 8.11$, $P<0.001$). Post hoc pairwise comparisons indicated that crewmembers who had the 1st and 3rd break obtained on average less sleep than those with the 2nd and 4th break ($P=0.005$) and less sleep compared to crewmembers with the first single break ($P=0.009$) or those with the second single break ($P<0.001$).

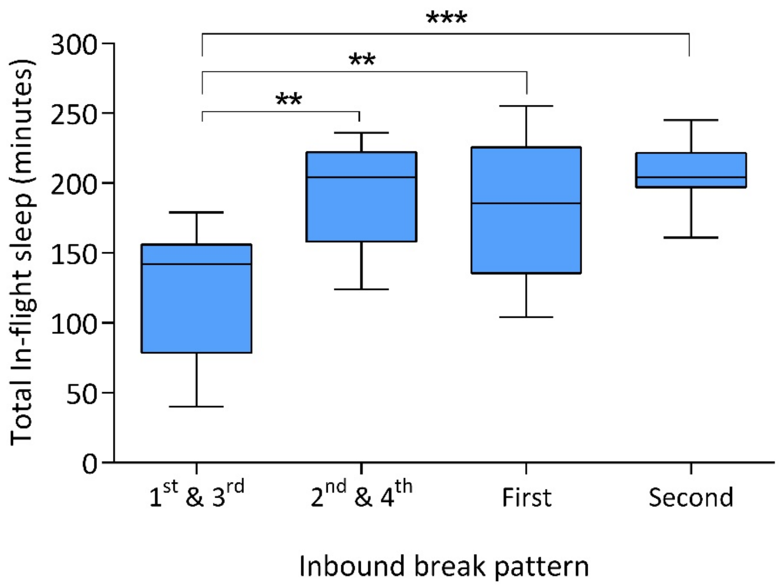

Figure 3-3 Total in-flight sleep (minutes) by rest break pattern on inbound flight[11]

Two sets of ANOVAs were run to determine if a pre-flight nap affected the amount of sleep obtained in-flight on the outbound flight (no crewmembers napped prior to the inbound flight due to the earlier departure time). The first model investigated whether there was an effect of having a nap or not on the total amount of sleep obtained in flight (all rest breaks combined). The second model investigated the effect on the amount of sleep obtained in the crewmembers' first rest break only. A pre-flight nap had no significant effect on the amount of sleep during the first scheduled break ($F(1, 53) = 1.07$, $P=0.31$), or on the total amount of in-flight sleep ($F(1, 53) = 0.04$, $P=0.84$).

[11] 1st & 3rd = first and third break; 2nd & 4th = second and fourth break; first = single break during first half of flight; second = single break during second half of flight. Each boxplot displays the middle 50% of data as a grey box, with the median value indicated by the horizontal line inside the box. The whiskers represent the minimum and maximum values. . Statistically significant post hoc pairwise comparisons are denoted by ** for P<0.01 and *** for P<.0001.

Ratings of fatigue and sleepiness were made eight times in association with each flight leg: pre-flight, at TOC, prior to the first break, after the first break, prior to the second break, after the second break, at TOD, and after landing. However, because of the variable pattern of rest breaks, the timing of the pre- and post-break ratings were not identical for crewmembers. Therefore the linear mixed model ANOVAs for repeated measures only considered the four common time points (pre-flight, TOC, TOD and after landing) and flight leg (outbound; inbound) as well as the interaction of these factors. As shown in Figure 3-4, subjective fatigue changed significantly across the flight ($F(3, 315)=89.23$, $P<0.001$), with crewmembers feeling least fatigued pre-flight and getting progressively more fatigued. Crewmembers also felt significantly more fatigued on the inbound flight than the outbound flight ($F(1, 317)=20.83$, $P<0.001$). Descriptive statistics are presented in Appendix U, Table U-2.

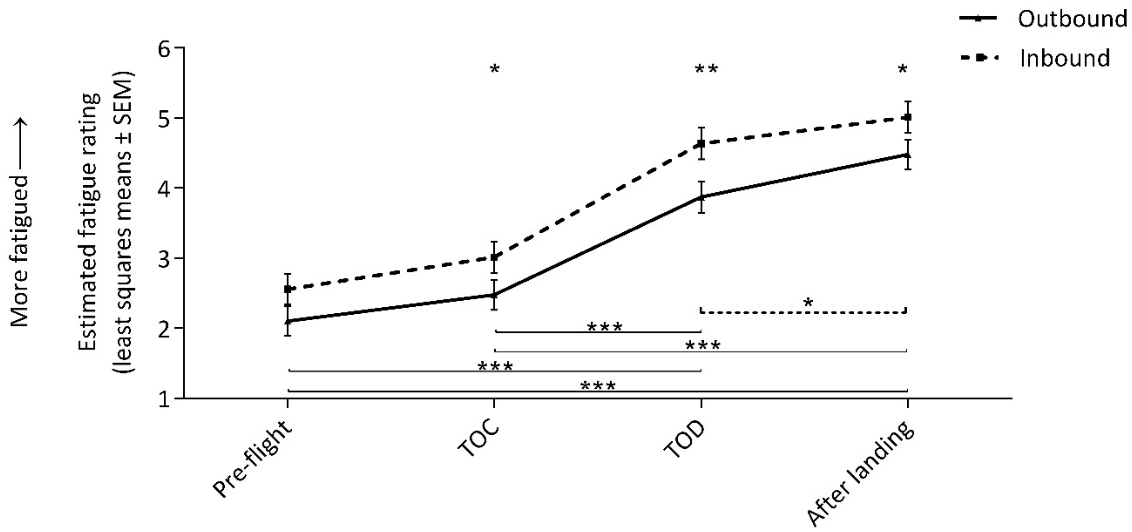

Figure 3-4 Mean estimated SP fatigue ratings across the outbound and inbound flights[12]

The same pattern was seen for subjective sleepiness, which changed significantly across the flight ($F(3, 311)=94.40$, $P<0.001$), with crewmembers feeling least sleepy pre-flight and progressively more sleepy. Crewmembers also felt significantly more sleepy on the inbound flight than on the outbound flight ($F(1, 313)=14.32$, $P<0.001$). Descriptive statistics are presented in Appendix U, Table U-3.

For PVT performance, linear mixed model ANOVAs considered two common time points (TOC and TOD) and flight leg as well as the interaction of these factors. On both flight legs, PVT response speed declined from TOC to TOD ($F(1, 96)=11.97$, $P<0.001$), and was slower on the inbound flight than the outbound flight ($F(1, 95)=5.97$, $P=0.02$), as shown in Figure 3-5. The same pattern of performance decline across the flight (from TOC to TOD) was seen for the fastest 10% of responses ($F(1,91)=5.35$, $P=0.02$), slowest 10% of responses

[12] Statistically significant post hoc pairwise comparisons are denoted by * for P <0.05, ** for P<0.01 and *** for P<0.001 Asterisks in top of figure denote differences between outbound and inbound. Solid connector lines indicate differences between rating times which were observed on both flight legs; the dashed connector line indicates a difference between ratings on the outbound flight only.

(F(1,97)=12.44, P<0.001) and lapses (F(1,96)=15.79, P<0.001). In addition, the fastest 10% of responses were faster on the outbound leg than on the inbound leg (F(1, 89)=10.60, P=0.002). Descriptive statistics are presented in Appendix U, Tables U-4 to U-7.

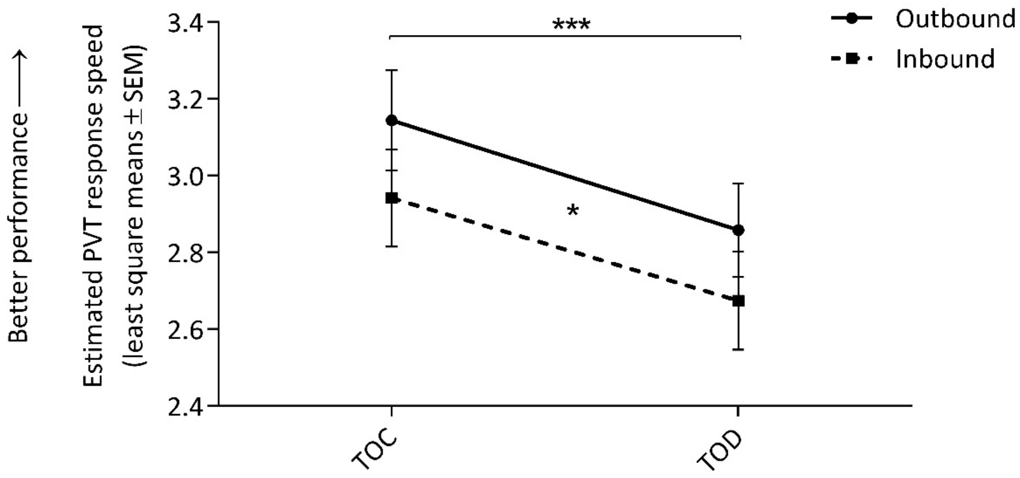

Figure 3-5 Mean estimated PVT response speed across the outbound and inbound flights[13]

Two sets of linear mixed model ANCOVAs investigated factors influencing fatigue, sleepiness and PVT response speed at TOD. The first set included the amount of in-flight sleep obtained, the duration of time awake at TOD, and flight leg. The second set was similar but included total sleep in the 24 hours prior to TOD instead of the amount of sleep obtained in flight.

With longer time awake at TOD, crewmembers felt more fatigued (F(1,56) = 6.58, P=0.01) and sleepy (F(1,75) = 5.06, P=0.03). No association was found between PVT response speed and prior wakefulness (F(1, 48) = 2.39, P=0.13). No associations were found between

[13] Statistically significant post hoc pairwise comparisons are denoted by * for P<0.05 and *** for P<.0001.

fatigue, sleepiness or PVT response speed and total in-flight sleep or total sleep in the 24 hours prior TOD.

As illustrated in Figure 3-1, the majority (85.3%) of crewmembers had more than one sleep episode in the first 24 hours of the layover, while in the last 24 hours of the layover, most (61.8%) only slept once, and for nearly all crewmembers (73%) this was during the local night (defined as at least 80% of sleep occurring between 22:00 and 08:00 local New York time).

Crewmembers obtained significantly more sleep per 24 hours on layover than on baseline days ($F(2, 158) = 11.93$, $P<0.001$). Post hoc pairwise comparisons indicated that estimated mean total sleep was 69 minutes longer in the first 24 hours of the layover than on baseline ($P<0.001$), but did not differ from baseline in the last 24 hours of the layover ($P=1.000$).

Crewmembers obtained almost 1.5 hours more sleep in the first 24 hours post-trip when compared to baseline days ($F(5, 281) = 8.64$, $P<0.001$) and 58% took a post-flight nap (see Figure 3-1). From post-trip day 2 onwards, the total amount of sleep did not differ from baseline days.

Fatigue and sleepiness ratings after night-time sleep (i.e. sleep occurring during the local night) on baseline days were compared to fatigue and sleepiness ratings after night-time sleep on post-trip days. Crewmembers were no more fatigued ($F(5, 237) = 1.07$, $P=0.38$) or sleepier after waking on any of the post-flight days compared to baseline ($F(5, 237) = 0.57$, $P=0.72$). Descriptive statistics are presented in Appendix U, Tables U-8 and U-9.

3.5 Discussion

The present study demonstrates that data collection is feasible for cabin crew on ULR trips. However, the response rate and completion rate tended to be lower compared to a recent study involving flight crew (Signal et al., 2014). Twenty seven percent of cabin crew declined to participate and the reasons for this are unknown. Of those who agreed to participate, 60% completed data collection and 41% provided data of suitable quality. Methods for improving recruitment and completion rates are therefore worthy of investigation.

In the present study, cabin crew generally prepared well for the ULR trip by obtaining on average more sleep in the 24 hours pre-flight compared to baseline days and almost half took a pre-flight nap. Baseline sleep averaged 6.5 hours per night, although this varied greatly between individuals. Not all crewmembers were free from duty on baseline days, but this was the best available estimate of normal sleep at home. In comparison, flight crew flying this same ULR route obtained on average 7.0 hours of sleep on baseline days (Signal et al., 2014). The reasons for this difference deserve further investigation, but may be due to differences in the demographics and domestic responsibilities between the two occupational groups. Almost half of the cabin crew were female and may have had a disproportionate level of domestic responsibilities (Craig & Mullan, 2010), which could impact on their night time sleep. Recurrent training that includes education on the importance of recovery sleep at home may be valuable for cabin crew.

Taking a pre-flight nap before the outbound flight did not influence the amount of sleep during cabin crews' first scheduled in-flight rest break or the total amount of in-flight sleep, as was also found for flight crew flying this same route (Signal et al., 2014). This finding reinforces that a pre-flight nap before an evening departure is feasible and does not appear to adversely influence subsequent in-flight sleep.

Crewmembers obtained on average more sleep on the ULR outbound flight (3.6 hours) than the non-ULR inbound flight (2.9 hours), which was in part facilitated by the longer flight duration and local evening departure of the outbound flight. However, the amount of in-flight sleep varied greatly between individuals. Age-related changes in sleep (Redline et al., 2004) were not evident in the in-flight sleep duration, but it is possible that actigraphy is not sensitive for detecting age-related changes in short in-flight sleep periods. The high inter-individual variability suggest that other personal, environmental and/or work-related factors may influence in-flight sleep and this warrants further investigation to develop recommendations for improving in-flight sleep.

As per company recommendations, the time available for rest in the bunk on the outbound flight was split into four rest breaks on almost all occasions. There are presently no company recommendations regarding in-flight rest patterns on the inbound flight. The findings do not indicate that splitting the available rest time into four rest breaks is better or worse than splitting the available time into two rest breaks. However the timing of the scheduled bunk rest breaks affected the amount of total in-flight sleep obtained on the inbound flight, with crew taking the 1st and 3rd break obtaining significantly less in-flight sleep compared to all other crew. Assuming minimal circadian adaptation during the layover, the 1st rest break would have fallen in the circadian evening wake maintenance zone (a few hours before a person's normal bedtime when sleep is difficult to initiate and maintain) on Johannesburg time, whereas the longer single break during the first half of the flight would have extended past the evening wake maintenance zone, allowing more sleep to be obtained. However, crewmembers taking the first long break would also have been awake longer at TOD than all other crewmembers and a longer duration of time awake at TOD (but not prior sleep) was associated with increased fatigue and sleepiness at TOD. On other ULR routes (Flight Safety Foundation, 2005a), a number of different break patterns have been used and preference is in part determined by the flight's departure window. Providing crew with two breaks each has the advantage of minimizing the risk of not obtaining any sleep if one of the breaks occurs during a less favourable time in the circadian body clock cycle for sleep (Flight Safety Foundation, 2005a).

In the last 24 hours of the layover, most crewmembers slept during the local night, despite being advised to stay on domicile time. This caused sleep to be truncated on the morning of departure, due to the local morning sign-on time and/or due to the crewmember's inability to stay asleep due to the circadian drive for wake. A pre-flight nap was not possible for most crewmembers due to the relatively short period of time between waking and sign-on, coupled with an adverse circadian phase for sleep (late afternoon Johannesburg time/morning New York time) during which initiating or maintaining sleep is difficult.

The context in which a PVT test is completed can differ greatly between workplace settings, as is the case for cabin crew in comparison to flight crew as well as for cabin crew at different phases of the flight. Although we cannot be certain, the poor performance on the outbound pre-flight PVT test may have been a result of distractions in the testing environment. Completion of the PVT in a busy cabin is expected to have contributed to the large variability observed in the subsequent tests, which in turn may also have contributed to the lack of a statistically significant association between sleep history and performance. On the other hand, a study using combined datasets from four field studies which included data from of 237 pilots on 730 long range and ultra-long range flights also found no association between PVT performance and sleep/wake history at TOD (Gander et al., 2015). Despite the more challenging context in which the PVT was completed, the PVT showed the expected changes in cabin crew's performance across the flight (from TOC to TOD) and between flight legs. Compared to flight crew however (Gander et al., 2015; Signal et al., 2014), cabin crew's PVT performance was overall slower and resembled more closely the performance of populations in other research studies (Wesensten, Belenky, Thorne, Kautz, & Balkin, 2004). In future studies the timing and/or location for completing PVTs should be carefully considered, in consultation with the cabin crew.

Fatigue and sleepiness ratings were overall higher and PVT response speed was slower on the shorter non-ULR inbound flight in comparison to the outbound ULR flight, even though both flights spanned the local Johannesburg night, assuming minimal adaptation during the layover. These findings indicate that longer flights do not necessarily result in greater declines in performance and increases in fatigue, especially if sufficient in-flight sleep is obtained. The greater fatigue experienced on the inbound flight may instead be a consequence of the accumulated sleep loss across the trip and suggests adequate recovery following such patterns of work is important.

The present findings suggest that four local nights off duty following the ULR trip is, on average, sufficient to enable crewmembers to recover from the trip. However, sleep duration varied greatly among individuals, as did the post-sleep sleepiness and fatigue ratings, which suggests that some crewmembers recover more slowly than others. Education on the importance of recovery sleep at home, including a consideration for individual differences in sleep need and recovery, would therefore be beneficial for cabin crew.

3.6 Conclusions

This study of cabin crew flying a ULR trip between Johannesburg and New York utilized recommended measures and methods for collection and analysis of data (Flight Safety Foundation, 2005b), allowing a robust scientific assessment of changes in sleep, sleepiness, fatigue and performance across the ULR trip. To our knowledge, this is the first ULR validation study involving cabin crew.

It demonstrates that cabin crew fatigue was managed effectively on the outbound ULR flight. It also demonstrates that this type of data collection is feasible for cabin crew, although operational differences between cabin crew and flight crew need to be considered in these data collection processes and a large number of cabin crew may need to be approached to obtain sufficient data. Multiple factors may influence the motivation of cabin crew to take part in the data collection and this warrants further investigation.

It is important to note that the findings from the present study cannot be generalized to operations with different flight durations, departure times and/or arrival times.

CHAPTER 4 PERCEIVED WORKLOAD IS ASSOCIATED WITH CABIN CREW FATIGUE ON ULTRA-LONG RANGE FLIGHTS

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This manuscript was prepared by the doctoral candidate (see Appendix X) and has been published in *The International Journal of Aerospace Psychology* (11 June 2019)[14].

4.1 Abstract

Objective: This study aimed to determine whether on ultra-long range (ULR) flights, perceived workload is an independent predictor of cabin crew fatigue at top-of-descent (TOD) and if so, to what degree it is associated with cabin crew fatigue relative to sleep-related factors.

Background: Current ULR scheduling for cabin crew is predominantly based on flight crew data. However, cabin crew workload is very different in nature to that of flight crew.

Method: Fifty-five cabin crew wore an actigraph and completed a sleep/duty diary to monitor sleep during a ULR trip between Johannesburg and New York. At TOD, crewmembers completed a 5-minute Psychomotor Vigilance Task (PVT), rated their sleepiness (Karolinska Sleepiness Scale) and fatigue (Samn-Perelli Crew Status Check), and after landing their workload (raw NASA Task Load Index).

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Results: When workload was perceived as higher, crewmembers felt more sleepy and fatigued and had more PVT lapses at TOD. The effect of workload on sleepiness was larger (Cohen's f^2= .27) than the duration of wakefulness (Cohen's f^2=.14), but the effect of workload on fatigue (Cohen's f^2= .17) was smaller than the duration of wakefulness (Cohen's f^2=.24). PVT lapses were not associated with sleep history, whereas workload had a small effect (Cohen's f^2=.14).

Conclusion: Workload as a fatigue factor for cabin crew warrants ongoing monitoring. This can be achieved by including a workload question as an essential component of cabin crew data used in Fatigue Risk Management Systems.

Keywords: Fatigue risk management, sleepiness, performance.

4.2 Introduction

Cabin crew are integral to maintaining cabin and passenger safety, as well as ensuring passenger comfort on commercial flights. However, working in a 24/7 industry poses a number of challenges for cabin crew. They often experience fatigue resulting from irregular work schedules, long duty periods, circadian rhythm disruption, sleep loss, and high workload (Avers, King, et al., 2009; Avers et al., 2011; Castro et al., 2015; Lowden & Åkerstedt, 1998b, 1999; MacDonald et al., 2003; Nesthus et al., 2007; Ono et al., 1991).

Fatigue, as defined by the International Civil Aviation Organization (ICAO), is "a physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to perform safety related operational duties" (International Civil Aviation Organization, 2016). Considering the potential consequences of fatigue-related impairment on safety-related performance, cabin crew fatigue and its associated risk needs to be managed carefully.

Prescriptive duty and rest regulations that set the daily maximum amount of time on duty, cumulative time on duty and minimum rest periods within and between duty periods, are traditionally used for managing fatigue, but only consider time-on-task fatigue. Fatigue Risk Management Systems (FRMSs) are a relatively new approach to managing fatigue that is based on scientific and operational knowledge about all known causes of fatigue that can lead to impaired performance (Cabon et al., 2008; Gander, Hartley, et al., 2011; International Civil Aviation Organization, 2016).

ICAO's FRMS guidelines, which were first developed with the advent of newer aircraft being able to fly more than 16 hours non-stop and therefore exceeding the maximum limits of traditional flight and duty time regulations, are applicable to both flight crew and cabin crew (International Civil Aviation Organization, 2016). Knowledge about cabin crew fatigue associated with these ultra-long range (ULR) flights is still very limited (van den Berg, Signal, Mulrine, et al., 2015) and current ULR scheduling for cabin crew is therefore predominantly based on flight crew data. However, there are differences to consider between these two groups. Notably, the workload of cabin crew is considerably different in nature from that of flight crew. Their duties involve a lot more physical tasks and walking, and factors such as turbulence, passenger demands, and medical incidents can significantly add to their workload (Avers, King, et al., 2009; Damos et al., 2013; Glitsch et al., 2007; Hagihara et al., 2001; Samel et al., 2002; Williams, 2003). The more intensive physical activity is also expected to exacerbate any fatiguing effects of mild hypoxia resulting from working in a pressurized cabin equivalent to 6000-8000 feet above sea level (Aerospace Medical Association et al., 2008; Muhm et al., 2007; Smith, 2007). It is therefore not surprising that cabin crews' workload has been identified as an important factor contributing to their fatigue (Bergman & Gillberg, 2015; MacDonald et al., 2003; Nesthus et al., 2007; Samel et al., 2002; Vejvoda et al., 2001).

Studies in other workplace settings that have assessed the influence of workload on fatigue have produced some important findings. For example, ratings of fatigue made by air traffic controllers have been shown to increase more rapidly with increasing hours of wakefulness when workload is perceived as high, in comparison to low or medium workload. In addition, the time-of-day effect observed in subjective fatigue ratings was more pronounced when workload was rated as either high or low than when it was rated as moderate (Spencer et al., 2000; Spencer et al., 1997). Shift workers at a metallurgic smelter who perceived their workload as high did worse on a psychomotor vigilance task midway through their 12-hour shift when compared to those who perceived their workload as low, more so during night shifts than day shifts (Baulk et al., 2007).

To our knowledge, no existing studies have directly assessed the influence of workload on cabin crew fatigue. Yet findings from the above-described studies indicate that this may be important for improving fatigue risk management for cabin crew.

As part of a study evaluating the effectiveness of fatigue risk management for cabin crew on an ultra-long range trip between Johannesburg and New York (van den Berg, Signal, Mulrine, et al., 2015), workload ratings were obtained from crewmembers at the end of the outbound and inbound flights (after landing, before disembarking the aircraft) to investigate the association of perceived workload with measures of cabin crew fatigue at top-of-descent (TOD), the point at which the aircraft transitions from the cruise phase to the safety-critical landing phase of flight. In the event of an emergency situation during this time, cabin crew are responsible for managing the cabin and the evacuation of passengers. The European Transport Safety Council has estimated that 90% of aircraft accidents are survivable, but fast and efficient evacuation is of vital importance (European Transport Safety Council, 1996).

The present analyses aimed to 1) determine whether on these ultra-long range flights, perceived workload is associated with cabin crew fatigue at TOD and if so, 2) to what degree perceived workload is associated with cabin crew fatigue, compared to sleep-related factors.

4.3 Methods

The study protocol was reviewed and approved by the Massey University Human Ethics Committee (application 11/74). Each crewmember provided written informed consent before participating. Participation was voluntary and confidentiality was strictly maintained.

4.3.1 Participants

All cabin crew rostered on a Johannesburg-New York-Johannesburg trip during the study period (27 August 2012 to 24 June 2013) were eligible to participate. Up to seven of the 14 crewmembers were recruited on each flight, as it was considered important to sample a range of flights in case conditions varied widely from one flight to the next, or in the event of peculiarities on one particular flight (e.g. delays, turbulence, and/or a medical event).

Fifty-five cabin crew participated in the study. Demographic information was available for 54 participants (29 females, median age = 37, range = 23-56 years; 25 males, median age = 36, range = 24-60 years) and are summarized in Table 4-1.

Table 4-1 Participant demographics

	Cabin crew [a] Median (range)	Pursers [b] Median (range)	Senior Pursers [c] Median (range)	All crew Median (range)
Age (years)	35 (23-60) [de]	41 (36-56)	43.5 (40-54)	36 (23-60) [e]
Work experience (years)	11.9 (1-38) [de]	14.8 (13-21) [e]	18.5 (17-23)	12.5 (1-38) [de]
Long-haul experience (years)	10.5 (1-19) [d]	14.7 (12-21) [e]	16.7 (0.6-18) [d]	12.0 (0.6-21) [d]
Average work hours per month	110 (55-150)	120 (90-165)	120 (80-120) [d]	110 (55-165)
Total number of crew	43	7	4	54

[a] Crewmembers who do not have management responsibilities; [b] Cabin crew member with in-flight management responsibilities in a specific cabin class; [c] Cabin crew member with in-flight management responsibilities who has the overall responsibility for the aircraft cabin; [d] Data not normally distributed; [e] Includes 1 outlier.

4.3.2 Measures

4.3.2.1 Sleep/Duty diary

Participants were provided with a sleep/duty diary in which to record demographic information, work experience, information about the flight, duty and in-flight rest periods, work position for the flight (Galley or Aisle; Premium or Economy), ratings of sleepiness, fatigue and workload. It also included a Post Duty Service Questionnaire.

4.3.2.2 In-flight sleep

To monitor their sleep in flight, participants wore an actigraph (Spectrum from Philips Respironics, Bend, Oregon, USA) on their non-dominant wrist. Data were recorded in 1-minute epochs and subsequently downloaded to a computer for analysis, using the manufacturer's software (Actiware® version 5.71.0, Philips Respironics, Bend, Oregon, USA) at the medium sensitivity setting, in conjunction with the sleep timing information from the sleep/duty diary.

4.3.2.3 Sleepiness and Fatigue ratings

Participants were asked to rate their sleepiness on the Karolinska Sleepiness Scale (KSS), on a scale from 1= 'extremely alert' to 9= 'extremely sleepy, fighting sleep' (Åkerstedt & Gillberg, 1990; Gillberg et al., 1994; Härmä et al., 2002). At the same time, fatigue was rated on the Samn-Perelli Crew Status Check (SP), on a scale from 1= 'fully alert, wide awake' to 7= 'completely exhausted, unable to function effectively' (Samn & Perelli, 1982).

4.3.2.4 Performance test

Performance was assessed with the Psychomotor Vigilance Task (PVT) (Dinges & Powell, 1985), which measures the ability of an individual to sustain attention and respond rapidly when presented with information. A validated, 5-minute version (Roach et al., 2006) (PalmPVT, Walter Reed Army Institute of Research) with an inter-stimulus interval of 2-10 seconds was programmed on a Palm Centro smartphone (Palm, Inc., Sunnyvale, California, USA).

4.3.2.5 Workload ratings

The NASA Task Load Index (NASA-TLX) is a multi-dimensional rating scale that was originally developed for use with flight crew (Hart & Staveland, 1988). Among four commonly used subjective workload scales, the NASA TLX has been shown to be the most sensitive to operator workload of military pilots (Hill et al., 1992). It has been used in a wide range of workplace settings to evaluate the influence of workload on fatigue (Baulk et al., 2007; Dorrian et al., 2011; Young et al., 2008), including studies with cabin crew (Roma et al., 2010; Vejvoda et al., 2000).

Workload ratings at the end of each flight were obtained using a modified version of the NASA Task Load Index (Hart & Staveland, 1988) that excluded the weighting component (Byers et al., 1989; Moroney et al., 1992) to reduce the study burden on participants. The six sub-scales measure mental demands, physical demands, temporal demands (i.e. time pressure), own performance, effort and frustration, on a scale from 0 to 100 in 5-step increments and anchored with the verbal descriptions 'Low' to 'High', except for the performance sub-scale which is anchored with the verbal descriptions 'Good' to 'Poor'. An overall workload index was obtained by averaging the six sub-scale scores.

4.3.2.6 Post Duty Service Questionnaire

Participants were also asked to complete an 11-item Post Duty Service Questionnaire (Roma et al., 2010) at the end of each flight, to document the number of passengers on the flight, the occurrence of flight delays, turbulence, disruptive passengers, medical or emergency incidents or major service disruptions, and how many times they assisted with baggage.

4.4 Procedure

The westward outbound flights (median flight duration = 16.0 hours) were scheduled to depart Johannesburg (JNB) at 20:40 local time, with a scheduled local arrival time of 6:40 (12:40 Johannesburg time) in New York (JFK). Following a 48-hour layover, the eastward inbound flights (median flight duration = 14.7 hours) were scheduled to depart New York at 11:15 local time (17:15 Johannesburg time), with a scheduled arrival time of 8:00 (1:00 New York time).

Fourteen cabin crew (including one senior purser and two pursers) operate the A340-600 aircraft on the JNB-JFK-JNB route, with a seat capacity of 317 (275 Economy class seats; 42

Business class seats). They work as A and B crews who alternate their in-flight rest periods during the cruise phase of the flight and both crews work during the take-off, meal services, and landing. Crewmembers usually work in the same cabin class (Economy/Business) and the same position (Galley/Aisle) on both flights.

On each flight at top of descent (TOD; at the end of the last meal service and within 90 minutes before landing), participants were asked to rate their sleepiness and fatigue, and complete a PVT test. At the end of each flight (after landing, before disembarking the aircraft), they were asked to rate their workload for the entire flight on the raw TLX.

4.5 Data management and statistical analysis

Actigraphic in-flight sleep recordings were scored using Actiware® software. The duration of each in-flight sleep was calculated as the number of minutes of sleep from sleep onset (the first 10 consecutive minutes scored as sleep by the software algorithm) until final wake-up (Signal et al., 2005). Using a custom-built program in MS Access, total in-flight sleep was calculated for each individual by summing in-flight sleep durations. Duration of time awake at TOD was calculated as the number of minutes between actigraphically determined final wake-up and time at TOD.

Data from the sleep/duty diary were entered in an MS Access database. Mean raw TLX scores for each participant were calculated by averaging the six sub-scales scores. Where a response was missing for one or more subscales, a mean score was not calculated.

Top-of-descent PVT data were downloaded using the PalmPVT software (Walter Reed Army Institute of Research, USA), and the REACT program (Ambulatory Monitoring Inc., USA) was used to generate summary statistics for each test. The four performance metrics reported here are PVT reciprocal response time (1/reaction time in milliseconds x 1000), fastest 10%

of reciprocal response times, slowest 10% of reciprocal response times, and lapses (reaction times exceeding 500 milliseconds in duration).

Descriptive statistics and non-parametric tests (Wilcoxon signed rank tests, Chi-square tests) were undertaken in SPSS (version 24.0, IBM SPSS Statistics for Windows, Armonk, NY, USA). Linear mixed models were undertaken in SAS (version 9.3, SAS Institute Inc., Cary, NC, USA). Participant ID was included as a random effect to account for individual differences. The Kenward-Roger adjustment was applied to the degrees of freedom estimation (Littell et al., 2006). Model assumptions were checked visually and the distribution of the residuals were tested with the Shapiro-Wilk test of normality and Levene's test for constant variance. If the variances were not constant, then a more conservative p-value was used ($p < 0.01$ instead of $p < 0.05$) (Tabachnick & Fidell, 2013). Polynomial regression models including quadratic and cubic terms of mean raw TLX scores were also undertaken in SAS to confirm a linear relationship between mean raw TLX scores and KSS, SP, PVT response speed, and lapses at TOD respectively.
To quantify the independent contribution of each fixed effect in the linear mixed models, Cohen's f^2 (Cohen, 1988) was calculated using the method described by Selya et al., (2012). Local effect sizes were classified as small ($f^2 = .02$), medium ($f^2 = .15$) or large ($f^2 = .35$) according to Cohen's guidelines (Cohen, 1988).

4.6 Results

Flight durations on the outbound (JNB-JFK) sector ranged between 15.3-16.7 hours (median = 16.0 hours), and flights on the inbound (JFK-JNB) sector ranged between 13.7-15.2 hours (median = 14.7 hours).

The majority of participants (n=34) worked in Economy class (on both flights Aisle: n=25; Galley: n=9), whereas n= 21 worked in Business class (outbound flight: Aisle: n=12, Galley: n=6, both n=3; inbound flight: Aisle: n= 14, Galley: n= 6, both: n=1).

As shown in Table 4-2, total in-flight sleep durations varied widely between participants on both the outbound and inbound flight, as did duration of time awake at TOD. Similarly, subjective sleepiness and fatigue, PVT performance and workload also ranged widely between participants. Univariate comparisons showed that participants obtained on average more inflight sleep on the longer outbound flight than the shorter inbound flight. They also rated their sleepiness and fatigue higher on the inbound flight. At the univariate level, PVT performance did not differ between flights, but a difference was seen in the multivariate models discussed below (for detailed analyses of in-flight sleep, KSS, SP and PVT measures, see van den Berg et al., 2015) .

Table 4-2 Sleep history, sleepiness, fatigue, PVT performance at TOD and workload on the outbound and inbound flights

Measure	Outbound				Inbound				
	n	Mean ± SD	Median	range	n	Mean ± SD	Median	range	p [b]
Total in-flight sleep (mins)	55	216 ± 44	223 [a]	98 – 303	55	175 ± 50	185	40 – 255	**.000**
Time awake (mins)	55	226 ± 88	245 [a]	104 – 468	55	246 ± 150	203 [a]	59 – 584	.555
Sleepiness ratings (KSS)	43	4.6 ± 2.0	5.0 [a]	1 – 8	43	5.3 ± 1.9	5.0	1 – 9	**.009**
Fatigue ratings (SP)	44	3.9 ± 1.7	4.0 [a]	1 – 7	43	4.6 ± 1.5	5.0 [a]	2 – 7	**.000**
PVT response speed	39	2.8 ± 0.8	2.8	0.9 – 4.3	33	2.7 ± 0.7	2.7	1.3 – 4.0	.133
PVT fastest 10% of	39	4.2 ± 0.9	4.1	2.2 – 5.8	33	3.9 ± 0.8	3.8	2.1 – 5.4	.056
PVT slowest 10% of	39	1.3 ± 0.8	1.1	0.2 – 3.1	33	1.1 ± 0.7	0.9 [a]	0.3 – 2.6	.247
PVT lapses	39	10.4 ± 10.0	7.0 [a]	0 – 38	33	11.6 ± 10.2	8.0 [a]	0 – 41	.290
Raw NASA TLX:									
Mental Demands	54	61.4 ± 29.6	70.0 [a]	10 – 100	54	62.8 ± 28.7	70 [a]	5 –100	.831
Physical Demands	53	65.2 ± 30.2	85.0 [a]	10 – 100	54	66.4 ± 31.2	80 [a]	5 –100	.519
Temporal Demands	53	48.0 ± 24.4	50.0	5 – 95	54	48.2 ± 26.6	43 [a]	5 –100	.992
Performance	53	24.8 ± 24.9	15.0 [a]	5 – 95	54	32.2 ± 28.1	20 [a]	5 –95	.065
Effort	53	64.3 ± 25.2	70.0	15 – 100	54	65.4 ± 25.5	75 [a]	15 –100	.756
Frustration	54	37.9 ± 30.2	20.0 [a]	5 – 100	53	44.4 ± 31.6	35 [a]	5 –100	.155
Mean raw TLX score	50	50.6 ± 20.6	53.0	9 – 95	53	53.7 ± 22.3	56.0	8 – 94	.232

[a] Data non-normally distributed; [b] Wilcoxon signed rank test

Median ratings on each of the six NASA TLX subscales, as well as the mean raw TLX score (the average of the six subscales) are summarized in Table 4-2. Scores on each subscale, as well as mean raw TLX scores, ranged widely between participants but did not significantly differ between the outbound and inbound flight.

The median number of passengers was 241 (range = 100-325, n = 32) on outbound flights and 266 (range = 120-317, n = 31) on inbound flights. Cabin crewmembers assisted with baggage on average twice on outbound (median = 2, range = 0-17 times) and inbound (median = 2, range = 0-23 times) flights. As shown in Figure 4-1, turbulence was the most frequently reported factor on both flights. Turbulence, as well as flight delays, medical incidents and major service disruptions were more frequently reported on the outbound flight than the inbound flight. Mixed model analysis of variance found no significant association between mean raw TLX scores and flight delays ($F_{(1, 55)} = 0.01$, p=.9229), turbulence ($F_{(1, 56.6)} = 0.00$, p=.9822), unruly passengers ($F_{(1, 44)} = 0.68$, p=.4151), medical incidents ($F_{(1, 47.3)} = 1.24$, p=.2707) or major service disruptions ($F_{(1, 56.9)} = 0.01$, p=.9055).

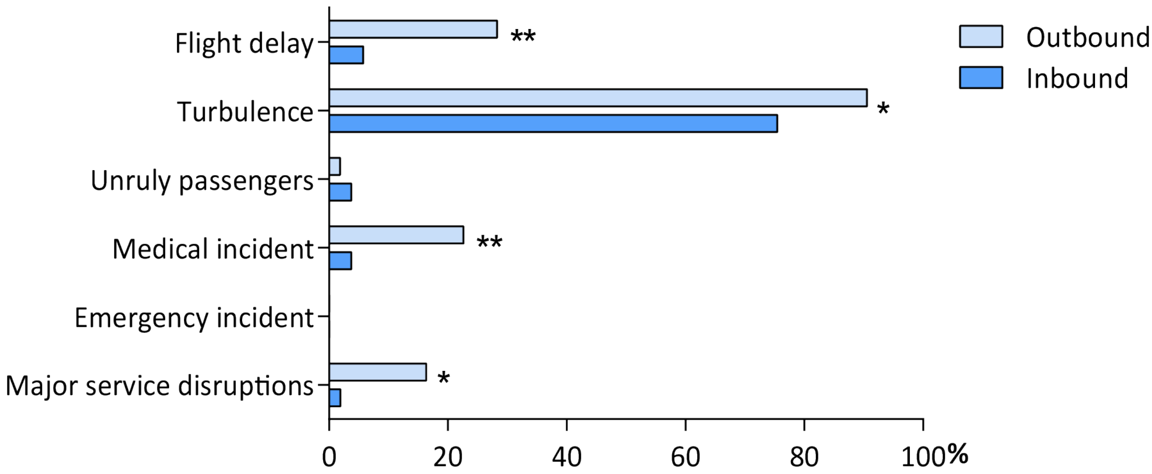

Figure 4-1 Percentage of cabin crewmembers experiencing in-flight disruptions (* p<0.05, **p<0.01, Chi-square test)

A second linear mixed model showed that perceived workload did not differ by cabin class ($F_{(1, 47.2)}$ = 1.06, p=.3095), work position ($F_{(1, 46.7)}$ = 0.70, p=.4062), work experience ($F_{(1, 46.0)}$ = 0.97, p=.3287), age ($F_{(1, 46.1)}$ = 0.19, p=.6684), or gender ($F_{(1, 46.9)}$ = 0.32, p=.5759), after controlling for flight sector and individual differences.

A third linear mixed model investigated whether perceived workload was associated with the amount of total in-flight sleep obtained, and/or the duration of time awake at TOD, after controlling for flight sector and individual differences. Perceived workload was not associated with the amount of in-flight sleep ($F_{(1, 76.5)}$ = 0.20, p=.6576), or the duration of time awake at TOD ($F_{(1, 69.9)}$ = 1.44, p=.2344).

Figure 4-2 illustrates the univariate relationship between mean raw TLX scores and KSS ratings, SP ratings, PVT response speed, fastest 10% of responses, slowest 10% of responses and lapses respectively. A set of linear mixed models were undertaken to determine whether each of these outcome measures was independently associated with perceived workload, in addition to total in-flight sleep, and/or duration of time awake at TOD, after controlling for flight sector and individual differences.

Quadratic and cubic terms of the mean raw TLX score were all non-significant in the above-described models, confirming linear relationships with the outcome measures.

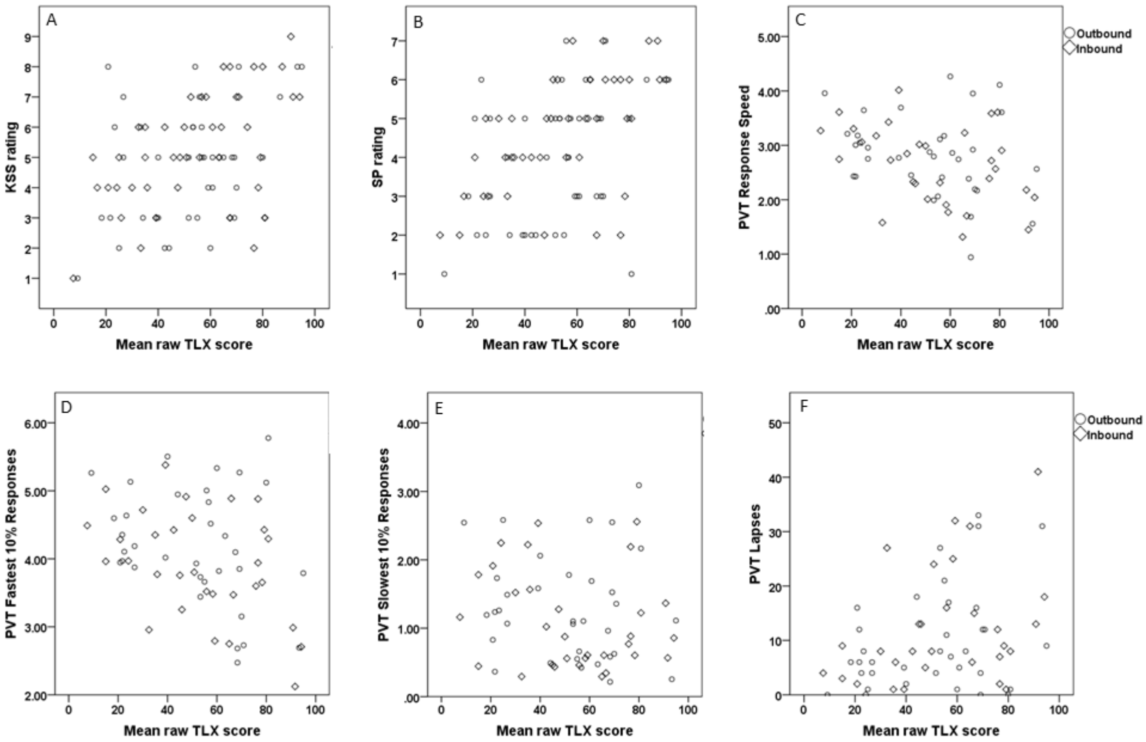

Figure 4-2 Univariate relationships between mean raw TLX score and A) sleepiness ratings (KSS), B) fatigue ratings (SP), C) PVT response speed, D) Fastest 10% responses, E) Slowest 10% responses and F) Lapses.

In the linear mixed models, subjective sleepiness (KSS) at TOD was associated with perceived workload as well as the duration of time awake at TOD, but the local effect of perceived workload on KSS ratings was larger (Cohen's f^2= .27) than the duration of time awake (Cohen's f^2=.14) (see Table 4-3). Subjective fatigue (SP) at TOD was associated with perceived workload, the duration of time awake at TOD, and flight sector. Among these associations, perceived workload had the smallest effect (Cohen's f^2= .17) on SP ratings at TOD. Perceived workload also had a small effect (Cohen's f^2=.14) on PVT lapses at TOD, whereas effect of sleep history or flight sector was not significant. All two-way interactions (workload × duration of time awake at TOD; workload × total in-flight sleep; workload × flight) were non-significant and therefore omitted from the final models.

Table 4-3 Linear mixed model results: total in-flight sleep, time awake, and workload as predictors of cabin crew's sleepiness, fatigue, and PVT performance at top-of-descent

Outcome measures	Fixed effect	β [e]	df	F	*p*	Cohen's f^2
Sleepiness rating (KSS)	Total in-flight sleep	0.0006	1, 79.7	0.03	.8685	.0001
	Time awake	0.0038	1, 76.9	6.39	**.0135**	.1413
	Mean raw TLX score	0.0353	1, 70.8	14.34	**.0003**	.2656
	Flight sector	0.5897 [f]	1, 45.9	3.45	.0695	.0805
Fatigue rating (SP) [a]	Total in-flight sleep	-0.0002	1, 70.5	0.01	.9355	.0033
	Time awake	0.0031	1, 63.1	7.52	**.0079**	.2347
	Mean raw TLX score	0.0299	1, 80.2	15.38	**.0002**	.1720
	Flight sector	0.6500 [f]	1, 38.4	9.08	**.0046**	.2503
PVT response speed [b]	Total in-flight sleep	-0.0012	1, 50.0	0.44	.5098	.0381
	Time awake	0.0008	1, 45.0	1.70	.1988	.0139
	Mean raw TLX score	-0.0063	1, 58.7	2.66	.1081	.3971
	Flight sector	-0.2682 [f]	1, 33.1	4.26	**.0469**	.1998
PVT fastest 10 % of responses	Total in-flight sleep	-0.0001	1, 58.0	0.00	.9670	.0002
	Time awake	0.0009	1, 52.9	1.28	.2637	.0388
	Mean raw TLX score	-0.0095	1, 55.8	4.03	.0497 [g]	.1026
	Flight sector	-0.2884 [f]	1, 38.0	2.65	.1120	.0937
PVT slowest 10 % of responses [c]	Total in-flight sleep	-0.0003	1, 44.9	0.10	.7555	.0207
	Time awake	0.0002	1, 39.9	0.47	.4984	.0134
	Mean raw TLX score	-0.0035	1, 59.8	3.43	.0690	.3729
	Flight sector	-0.0851 [f]	1, 31.4	2.16	.1515	.1177
PVT lapses [d]	Total in-flight sleep	0.0005	1, 52.4	0.19	.6651	.0265
	Time awake	-0.0004	1, 47.6	1.07	.3060	.0209
	Mean raw TLX score	0.0049	1, 53.7	5.34	**.0247**	.1427
	Flight sector	0.0975 [f]	1, 31.4	1.56	.2208	.0977

[a] Includes 1 outlier; [b] Excludes 1 outlier; [c] Square-root transformed; [d] Log10 transformed, excludes 4 outliers; [e] Fixed effects parameter estimates of the mixed model; [f] Reference = 'outbound'; [g] Variance not constant therefore a more stringent alpha-level of 0.01 was adopted.

4.7 Discussion

The present findings indicate that cabin crew flying this ultra-long range (ULR) trip felt more sleepy and fatigued, and lapsed more often at top-of-descent, when they perceived their workload as higher. The effect of perceived workload on subjective sleepiness was greater than that of the duration of time awake at top-of-descent (TOD). On the other hand, the effect of perceived workload on TOD fatigue ratings was smaller in comparison to the effect of the duration of time awake and flight sector. While psychomotor vigilance performance at TOD was not affected by prior sleep history, perceived workload had a small effect, with crewmembers lapsing more often when workload was perceived as higher.

In the present study, cabin crew had been awake for at least an hour (see Table 4-2) prior to TOD. Based on previous studies showing that the effects of sleep inertia dissipate within the hour or less after waking, sleep inertia was not expected to significantly influence measures of fatigue at TOD (Achermann et al., 1995; Hilditch et al., 2016; Signal et al., 2012; Wertz et al., 2006). Furthermore, as a possible consequence of a less conducive sleep environment, the in-flight sleep of pilots during a 7-hour rest opportunity was found to contain very little slow wave sleep, thus reducing concerns about exacerbating sleep inertia (Signal, Gander, et al., 2013).

On average, perceived workload did not differ between the outbound and inbound flights, even though turbulence, medical incidents, and major service disruptions, which are factors that reportedly increase the workload of cabin crew (Avers, King, et al., 2009; Damos et al., 2013), occurred more often on the outbound flights. However, in the present study no associations were found between these factors and perceived workload. It is possible that other aspects of the flight that were not recorded could have influenced the perceived workload of cabin crew, such as the frequency of meeting passengers' needs. On the outbound flight, which due to its evening departure would be considered a night flight, the majority of passengers would be expected to sleep for a significant part of the flight, in contrast to the inbound flight, which due to the late morning departure from New York, would be considered a daytime flight. However, Hagihara and colleagues (2001) who examined the number of steps taken by cabin crew on long-haul flights, found that contrary to expectations, the mean number of steps increased as flights spanned more night time hours. The authors argued that even though most passengers would be expected to sleep during nighttime hours, those who do not might require more frequent attention from cabin crew.

In the present study, no differences were observed in perceived workload between work position (Galley versus Aisle) or between Economy and Premium class. This is in contrast to other authors who attributed higher workloads to Economy class, based on the observation that cabin crew working in this class had higher blood pressure levels and heart rates compared to those working in Business and First class (Vejvoda et al., 2000). It is possible that in the present study, any differences in workload between cabin classes was ameliorated by having additional cabin crew on board to enable the scheduling of in-flight rest breaks for sleep on these longer flights.

The present study also did not find any age-related differences in perceived workload. In a recent study, middle-aged cabin crew reported that workload becomes more difficult to manage in older age as the demanding work hours and cabin equipment become more challenging (Bergman & Gillberg, 2015). On the other hand, it could be argued that older crewmembers have more work experience, which might lessen the effort required to meet certain work demands. However, in the present study, years of work experience was also not associated with perceived workload.

Consistent with reports from previous cabin crew studies (Castro et al., 2015; Glitsch et al., 2007; Nesthus et al., 2007), the physical demands contributed on average the most to cabin crews' perceived workload on these flights. Previous research has shown that high physical workload and high work demands predict disturbed sleep, with the latter possibly having an indirect effect on sleep through the need to 'unwind' after a work period (Åkerstedt et al., 2002). This is an important consideration for the scheduling of in-flight rest breaks, as the effect of cabin crews' workload on subsequent sleep is likely to reduce its recuperative value.

4.8 Limitations and future research

There are a number of limitations associated with the present findings. As an observational study, no cause-and-effect relationships could be established between workload and fatigue measures. In addition, using a subjective workload measure also introduces the possibility that the supposed effects of perceived workload, such as fatigue, might in fact become a cause of workload. Therefore, a possible bi-directional relationship between perceived workload and fatigue cannot be ruled out (Bowling & Kirkendall, 2012; Hockey et al., 1998; Mejri et al., 2014).

Another important caveat to these study findings is that they apply only to ULR flights with similar departure and arrival times, as the circadian timing of in-flight rest breaks, and rating times, strongly influence crewmembers' sleep, fatigue, and performance.

Furthermore, the findings cannot be generalized to other flights that operate with fewer crewmembers, or shorter flights with less or no opportunity for rest and/or a different workload distribution.

Further research is warranted to determine to what extent workload influences cabin crew fatigue on other types of operations. Compared to ULR flights, the effect of workload on fatigue during long-haul flights is expected to be greater as these typically operate with fewer crewmembers and allow less opportunity for in-flight rest, despite similar passenger loads and in-flight services. The effect of workload is expected to be greatest on short-haul flights, depending on the number of crew on board, in-flight services offered, and number of flight sectors flown per duty period. Importantly, these flights should not be considered in isolation, as any flow-on effects of workload on subsequent sleep could contribute to cumulative sleep loss and fatigue across a roster worked.

4.9 Conclusion

Taken together, the present findings indicate that workload is an important factor contributing to cabin crew fatigue on ULR flights and therefore warrants ongoing monitoring. This can be achieved by ensuring that in future studies investigating fatigue in cabin crew, measures of workload are included, and by incorporating a workload question in fatigue reports. Voluntary fatigue reporting by crewmembers form an essential component of FRMS for identifying potential fatigue hazards (International Civil Aviation Organization, 2016). For example, if workload was identified as a contributing factor in a series of fatigue reports on a particular route, this would prompt further investigation and if deemed necessary, lead to changes being made, for example to the delivery of service, or staffing levels.

CHAPTER 5 FATIGUE RISK MANAGEMENT FOR CABIN CREW: THE IMPORTANCE OF COMPANY SUPPORT AND SUFFICIENT REST FOR WORK-LIFE BALANCE – A QUALITATIVE STUDY

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This manuscript was prepared by the doctoral candidate (see Appendix X) and has been published in *Industrial Health* (17 April 2019)[15].

5.1 Abstract

Knowledge about cabin crew fatigue associated with ultra-long range (ULR) flights is still limited. Current ULR scheduling for cabin crew is therefore predominantly based on flight crew data. Cabin crews' views on fatigue, and their strategies for mitigating it, have seldom been sought. To better understand the causes and consequences of cabin crew fatigue, semi-structured focus group discussions were held. Thematic analysis was undertaken with data from 25 cabin crew. Participants indicated that the consequences of fatigue are twofold, affecting 1) cabin crew health and wellbeing and 2) safety (cabin, passenger and personal) and cabin service. While the primary causes of fatigue were sleep loss and circadian disruption, participants also identified other key factors including: insufficient rest, high workload, the work environment, a lack of company support, and insufficient fatigue management training. They highlighted the importance of sufficient rest, not only for obtaining adequate recovery sleep but also for achieving a work-life balance. They also

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highlighted the need for company support, effective communication, and management's engagement with cabin crew in general. We recommend that priority is given to fatigue management training for cabin crew, which may also enhance perceived company support and assist with achieving a better work-life balance.

Key terms: fatigue risk management system (FRMS), commercial aviation, work-life balance, focus groups, thematic analysis

5.2 Introduction

The aviation industry offers 24/7 service, which creates a number of challenges for cabin crew. They often experience irregular schedules, long duty periods, circadian rhythm disruption, sleep loss and high workload, which have all been shown to be contributing factors to cabin crew fatigue (Avers, King, et al., 2009; Avers et al., 2011; Castro et al., 2015; Holcomb et al., 2009; Lowden & Åkerstedt, 1998b, 1999; MacDonald et al., 2003; Nesthus et al., 2007; Ono et al., 1991).

For example, a field study which monitored the sleep of 202 cabin crew during a 3-4 week period showed that they obtained an average of 6.3 hours sleep on free days, 5.7 hours of sleep on work days, and even less when operating international flights (mean = 4.9 hours)(Roma et al., 2010). However, recently consensus has been reached that adults require 7-9 hours of sleep per day for maintaining optimal functioning and health (Hirshkowitz et al., 2015; Watson et al., 2015).

Sleep loss occurs not only as a consequence of working irregular hours, but also due to circadian rhythm disruption caused by rapid travel across multiple time zones (Atkinson et al., 2014). Jet lag has been associated with sleep disturbance during layovers and post-trip at home (Härmä, Laitinen, et al., 1994; Härmä, Suvanto, et al., 1994; Lowden & Åkerstedt, 1998a, 1999; S Suvanto et al., 1993; Vejvoda et al., 2000).

It is therefore not surprising that cabin crew experience work-related fatigue. In a large-scale survey with 9180 cabin crew, 84% percent reported being fatigued while on duty, of which 71% reported that their safety-related performance was affected, and 52% reported that they had 'nodded off' while working on a flight (Avers, King, et al., 2009).

Considering the important role of cabin crew in maintaining passenger and cabin safety, cabin crew fatigue and its associated risks needs to be managed carefully.

Traditionally, fatigue risk has been managed through prescriptive limits on maximum duty durations and minimum rest durations within and between duty periods. This 'one-size-fits-all', single-layer defensive strategy is adequate for some type of operations, but it does not take into account all known causes of fatigue that can lead to impaired performance (Cabon et al., 2008; Gander, Hartley, et al., 2011).

Fatigue Risk Management Systems (FRMSs) are a relatively new approach to improving safety and increasing operational flexibility. The International Civil Aviation Organization (ICAO) has defined FRMS as "a data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness". Advances in sleep science are integrated with safety science using similar processes and procedures to an airline's Safety Management System (SMS) for managing other types of hazards (International Civil Aviation Organization, 2016). ICAO's FRMS guidelines, which are applicable to both flight crew (i.e. pilots) and cabin crew, were developed with the advent of newer aircraft able to fly more than 16 hours non-stop, thus exceeding the maximum limits of traditional flight and duty time regulations. To manage the fatigue risk associated with these ultra-long range (ULR) flights, defined as flight operations between a specific city pair in which at least one of the flight sectors regularly exceeds 16 hours planned flight time (Flight Safety Foundation, 2005b), airlines are usually required to put in place an FRMS.

Current ULR scheduling and FRMS processes for cabin crew are predominantly based on flight crew data, as information on cabin crew fatigue associated with ULR flights is very limited (van den Berg, Signal, & Gander, 2015; van den Berg, Signal, Mulrine, et al., 2015). Hence, little is still known about how well current FRMS processes work for cabin crew. As an example, the main fatigue mitigation for ULR flights is to provide in-flight breaks and crew rest facilities in which crewmembers can obtain sleep. However, due to the requirement for all cabin crew to be awake for meal services, they have less time available for inflight rest compared to flight crew. In addition, in many countries the regulatory requirements for on-board rest facilities are less rigorous for cabin crew than for flight crew (Banks et al., 2009).

Cabin crew workload is also considerably different in nature from that of flight crew. Cabin crew duties include more physical tasks and walking. In addition, passenger demands, medical incidents, and turbulence, can significantly add to their workload (Avers, King, et al., 2009; Damos et al., 2013; Glitsch et al., 2007; Hagihara et al., 2001; Samel et al., 2002). This may have implications for the rest requirements for cabin crew. However, current scheduling does not take into account the relationship between workload and the high levels of fatigue frequently experienced by cabin crew (Nesthus et al., 2007).

Findings from a field study conducted with cabin crew flying a ULR trip between Johannesburg and New York showed that overall, the fatigue mitigation strategies used for flight crew on this route were also effective for managing cabin crew fatigue. However, large individual differences were observed in the amount of sleep obtained by cabin crew, not only in flight, but also at home and on layover (van den Berg, Signal, Mulrine, et al., 2015). Furthermore, compared to flight crew flying this same route, cabin crew obtained on average less sleep pre-trip and in flight, and a larger proportion experienced sleepiness while on duty (van den Berg, 2016). This suggests that a greater diversity of personal, environmental, and/or work-related factors may have influenced their sleep, which warrants further investigation in order to develop better recommendations for improving fatigue management for cabin crew (van den Berg, Signal, Mulrine, et al., 2015).

Importantly, fatigue is affected (negatively or positively) by activities outside of work as well as by work-related ones and can be considered a 'whole of life issue' (Gander, Hartley, et al., 2011). As such, fatigue management must be a shared responsibility between the employer and employee. To be able to reduce or mitigate fatigue, the causes and consequences of fatigue need to be understood. However, cabin crews' views on fatigue and their strategies for mitigating it, have seldom been sought.

The present study aimed to better understand cabin crews' views on fatigue, and how it might affect safety and their job performance, particularly in the context of ULR operations. Because the experience of fatigue is widely shared among cabin crew, semi-structured focus group discussions were considered the best choice for this purpose. Through the process of group interaction, these discussions can generate a large volume of enriched data to obtain a greater variety of views, opinions and experiences and were therefore preferred over individual interviews, or quantitative methods such as surveys (Braun & Clarke, 2013; Hennink, 2007).

Specifically, cabin crews' perspectives were sought on the following: the causes of cabin crew fatigue at home and at work; the consequences of cabin crew fatigue at home and at work; how their fatigue is currently managed at home and at work and what could be changed to reduce their fatigue.

As ULR operations continue to expand in the aviation sector, this study is, to the best of our knowledge, the first to seek the perspectives of cabin crew with ULR experience.

5.3 Subjects and Methods

Semi-structured focus group discussions were used to obtain a variety of views, opinions, and experiences from participating cabin crew. The study was reviewed and approved by the Massey University Human Ethics Committee: Southern A (Application 13/45).

5.3.1 Subjects

All cabin crew who had flown the Johannesburg-New York ULR route (average outbound flight duration=15.9 hours, inbound= 14.7 hours) were eligible to participate (total potential participants around 1500). The aim was to conduct at least three focus groups with 8-10 participants each. Cabin crew were required to respond to an advertisement in the company's communication channels within a set time period, so that they could be scheduled to ground-based duty on the dates that focus groups were to be run. Of the 33 crewmembers who volunteered, 27 could be scheduled to ground duty and were assigned to one of three focus groups (group size of 9). One crewmember did not attend, leaving 26 participants. As per ethical requirement, participants had the right to withdraw from the study either during the session or upon receipt of the transcript. They were not required to provide a reason for this. Of the 26 participants, one withdrew his/her data after reviewing the transcript. The results of the thematic analysis are therefore based on data from 25 participants.

Written consent was obtained prior to the start of the focus group discussion.

5.3.2 Procedure

Focus group discussions were scheduled across two consecutive days (20-21 February 2014) in a classroom at the airline's head office. A gift voucher (ZAR500) was offered before the start of the discussion as remuneration for participants' time to review their contribution in the transcript and for foregoing allowances associated with flying duty.

Each focus group discussion was facilitated by the first author and a research assistant. The first author, a PhD student currently working on the topic of fatigue risk management systems for cabin crew, has previous field research experience on the topic of fatigue management in flight crew and personal experience with shift work. She did not have a direct relationship with the participants and was not acting on behalf of the airline. The research assistant was a fellow cabin crewmember employed at the airline and knew some of the participants, but who did not hold a position of authority.

Prior to the start of the focus group discussion, participants were asked to complete a demographic questionnaire with information on age, gender, and work experience. The interview script included a brief introduction to reiterate the purpose of the study and the participants' right to withdraw at any time. Participants were also given the opportunity to ask any further questions before the audio recording was started. The discussion was preceded by a quick warm-up question in which each participant was invited to introduce him/herself. Eight key questions (see Table 5-1), formulated by the research team utilizing their significant experience of fatigue in aviation and FRMS, were used to guide the discussion and were displayed as visual prompts on a poster. These questions were designed to act as a memory aid for the group moderator, assist in managing the discussion around the studied topic, as well as ensuring consistency in questioning across the different focus groups (Hennink, 2007). Since no new issues were raised during the third focus group discussion, no additional focus groups were undertaken.

Table 5-1 Questions guiding the focus group discussion

Question 1	When you are at home, what makes you fatigued?
Question 2	When you are at work what makes you fatigued?
Question 3	How does fatigue affect you, when you are at home?
Question 4	How does fatigue affect you, when you are at work?
Question 5	Are there safety-related tasks at work that are affected by your fatigue?
Question 6	How do you currently manage your fatigue at home? (what strategies do you use to cope, countermeasures)
Question 7	How do you currently manage your fatigue at work?
Question 8	If you think that fatigue is a safety concern in flight, what do you think could be changed for cabin crew?

5.3.3 Data Analysis

Audio recordings were transcribed verbatim by an experienced staff member of South African nationality at the Sleep/Wake Research Centre. Each data extract includes a reference to its source (group number, ID). Where surplus or irrelevant information was excluded from a quote, the exclusion was denoted by […]. Pauses were denoted by '…' and words that were spoken with strong emphasis were <u>underlined</u>. Transcripts were crosschecked against the audio recordings by the researcher, corrected as required, and then anonymized. Participants were given the opportunity to check, edit or withdraw their contribution and their written approval was sought to have their data included in the analysis.

To situate the present research within the existing knowledge of fatigue risk management (International Civil Aviation Organization, 2016; Maurino, 2017), a pragmatist approach was adopted, which is a practical and applied research philosophy focused on producing 'real-world' knowledge that is solution-focused (Morgan, 2007). Thematic analysis was undertaken using a 6-phase iterative process described by Braun and Clarke (2006). Coding and theme development were undertaken using NVivo 10 (QSR International, Melbourne, Australia). To obtain a degree of verification, member reflections (Tracy, 2010) were sought by giving participants the opportunity to comment on the findings.

5.4 Results

The three groups were very similar in terms of age, gender, crew position, work experience, and average work hours per month (Table 5-2). The proportion of males (66-77%) was considerably higher than the proportion of male cabin crew working at this company at the time (about 34%). In Group 1, but not Groups 2 and 3, the majority of participants had taken part in a previous ULR validation field study (van den Berg, Signal, Mulrine, et al., 2015). All participants had ULR experience and had received fatigue management training as required prior to commencing ULR flying.

Table 5-2 Demographic information by group

		Group 1	Group 2	Group 3
Age (mean; range)		40 (29-62)	39 (33-50)	41 (24-52)
Gender:	Male	6	7	6
	Female	3	2	2
Crew position:	Cabin crew	6	6	5
	Purser	2	1	1
	Senior Purser	1	2	2
Work experience (mean; range)		16 (7-43)	13.5 (8-20)	16.5 (4-30)
Average work hours per month (mean; range)		110 (90-133)	120 (90-120)	120 (100-140 [a])
Years ULR experience (mean; range)		2 (1-3)	3 (1-3)	3 (1.4-4 [b])
Took part in ULR field study [c]: Yes		7	3	3
Number of participants		9	9	8

[a] Excludes 1 outlier (27 hours); [b] excludes 1 outlier (13 years); [c] van den Berg et al, 2015.

There was general consensus that cabin crew fatigue is inherent to the nature of the work: “*The nature of this job in itself will have a lot of fatigue [...] it is an international airline so it will travel at the wrong time, so that is the nature of the job*” (Group 2, J).

The consequences of fatigue were shown to be twofold for cabin crew. Firstly, there were various effects on health and wellbeing, including the inability to function at home on the first day after an international flight, weight increase, and a lowered immune system increasing the likelihood of getting sick and/or becoming unfit to fly as a result of ill-health: *“So, you come back to work with a compromised immune system and you are expected to work long hours. You’re about to get tired, your immune system cannot take it, your mind, your body just shuts down”* (Group 3, D). Secondly, effects on safety and service were reported, resulting from increased irritability, decreased alertness, forgetfulness, and performance changes, as well as falling asleep uncontrollably. Although it was said that their safety training and working as part of a team enabled fatigued cabin crew to handle emergency situations, there were nevertheless concerns about safety being compromised: "*and also I am concerned in an evacuation if you needed to do an evacuation, if 90% of us are well rested that 10% are still in need, we need them to be alert but if they are not, it might not be as fast as effective as it would have been if we were all well rested. So those things have not happened yet, but they can happen. So they need to look into making sure that we have as much rest as possible before, during and after the flight*" (Group 3, A). Not only were participants concerned about safety at work, but also driving home, with several reporting that they had fallen asleep.

Many factors contributing to fatigue were identified, often in conjunction with suggestions for changes to reduce it. The themes are described in the following sections and the recommended strategies associated with each theme are summarized in Figure 5-1.

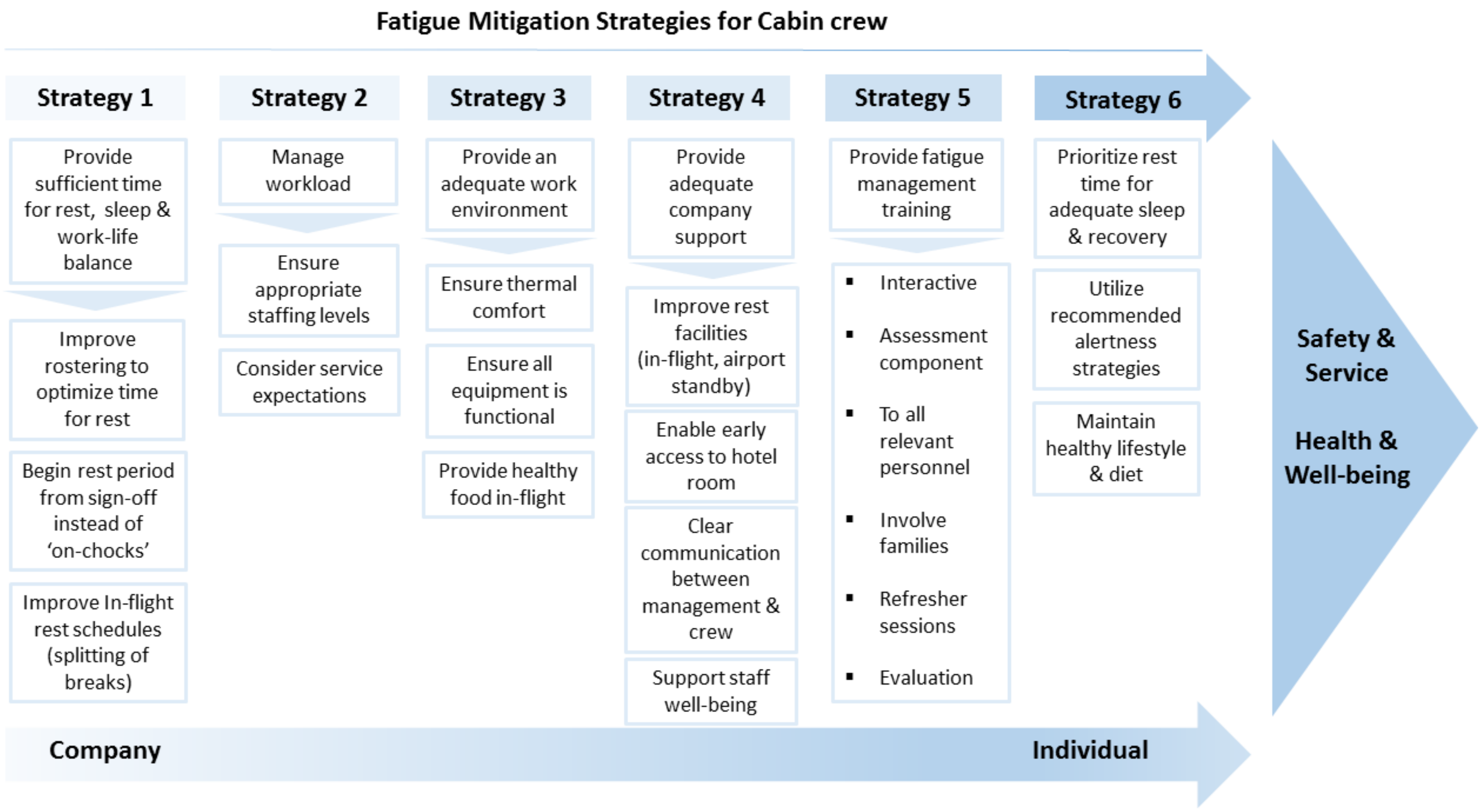

Figure 5-1 Fatigue mitigation strategies for cabin crew at company and individual level (modified from Moore-Ede, 2009)

5.4.1 Insufficient rest

When participants talked about rest, this usually included sleep but also time for relaxation. Insufficient rest was considered a significant cause of fatigue attributed to several factors. Firstly, rest between duty periods starts from 'on-chocks' when the aircraft's engines are shut down, but cabin crew duties continue until the passengers are deplaned. "*They give you minimum rest in terms of rest like 12 hours, it does not start from time of sign off. It starts from chocks. By the time you get home you have 10, 9 or 8 hours*" (Group 1, D).

Secondly, participants indicated that, although the minimum rest requirements may be sufficient for recovery from sleep loss, they are not sufficient for having a normal life at home: "*I just think that when you get home, even if it is not always possible, try and take a nap [...] it is different for everybody, but you really make the best of your off days. Like F says, you have things to do, you have got a life and you also have to rest, so you try and incorporate everything into two days. Two days is not enough for your life, because your life is not just flying, you know*" (Group 3, A).

While some participants stated that they would prioritize sleep, others indicated that there was generally a trade-off between sleep and other activities in the limited time available. Both male and female participants indicated that they attend to family and domestic responsibilities at home during the day. With these competing demands, family could also become a source of stress: *"The other thing I definitely say is stress, the stress we get from our families, you know. You have come back from overseas and your son had a volleyball game and then they start blaming, but ...you know this job that you do, you can't even go to your son's activities and then to think of that, yeah, it does affect you"* (Group 1, H).

Insufficient rest was also linked to several other factors, particularly rostering (i.e. the scheduling of work and rest), which participants viewed as the primary cause of the cumulative effects of sleep loss and circadian disruption. Specific aspects of the roster that they considered fatiguing included the combination of short-haul, long-haul and ULR flights, the limited number of days off before and after trips, and the irregular, and long work hours: "*I think the major, major, major problem here is the scheduling, the rostering of the flights that's the major thing. Like, for example, you cannot be signing on at 4:45 in the morning and then knocking off at 5 in the afternoon, you can sign in at 4:45 and then knock off at 9 or 10am, that you could manage just fine, as like B said, you are fatigued. So the major issue is rostering, if they could get that right*" (Group 2, H). Roster changes were the most frequent suggestions for improvement. These included maximizing rest breaks between duty periods by changing the combination of flights, reducing the number of successive 'hectic' flights to reduce their cumulative effects, shortening very long turnaround times to reduce long duty days, and reducing the number of work hours per month.

Participants also raised issues with the crew rest facilities and timing of scheduled breaks (relative to their body clock) affecting sleep during long-haul and ULR flights. On short-haul duty days, time for rest could be very limited when turn-around times were very short. Positive comments were made about the Johannesburg-New York ULR trip having a day off before the trip, the splitting of in-flight rest breaks to enable at least one break to coincide with a more favourable circadian time for sleep, and the option of an additional rest in a seat on the longer outbound leg. However, participants queried why the shorter inbound leg was not treated as ULR for managing the fatiguing effects of the trip: *"On that New York flight it is interesting, only the one leg is ultra-long. Now which is very funny, okay, here is why I have a problem, ultra-long to this point, but to get back to my house which is in Johannesburg, I have to fly this other leg that is not ultra-long, where you should look at the whole* <u>*picture*</u> *as one. You take what you want to be as ultra-long but the other you forget. And that other leg still affects me, so this is where I can't agree with you say "okay I will take this, but I will forget about this" (Group 3, H).* One of the most frequent suggestions for reducing fatigue during

ULR trips was to also split the rest breaks on the shorter inbound leg. Another suggestion related to the location of designated rest seats, with participants highlighting the importance of being able to sit away from passengers during their rest opportunity: "*On the New York and Beijing flight, the airline has booked off seats for the crew, but those seats can be anywhere. Sometimes they are right in the middle of two passengers […] you cannot sit and have your catnaps there in the middle of passengers and whatever. It needs to be a secluded area or it needs to be a business class seat like they do for the cockpit*" (Group 1, E).

Layover factors contributing to fatigue included having to wait to access the hotel room, the hotel being in a noisy location, and the time and effort needed to access amenities in the area. However, participants also indicated that the layover's destination could influence the amount of time spent on rest versus recreation: "*It's New York. You not gonna just sit in your room and you want to go out and you want to go and explore and we do, it's how we roll*" (Group 3, B).

Participants' recommendations for improving rest are summarized in Figure 5-1 under 'Strategy 1', 'Strategy 4', and 'Strategy 5'.

5.4.2 Workload

Workload was also considered to cause fatigue. Identified factors increasing workload included the range of duties and staffing levels on the aircraft, demands and complaints of passengers, and the service expectations of the company. On flights operating with minimum crew, or with a shortage of crew as a result of crewmembers being sick, workload was a major issue, particularly when the delivery of service to passengers was already under time pressure: "*And cutting down the manpower, that has changed our work environment; the load on per person has increased because of that. Like with the Durban trying to do it with 2 people with the 800, we used to be 3 and we are working with people short now* *and therefore the workload is a lot more, and sometimes, through nobody's fault, people book off and then there is no people to go around and therefore we fly crew members short and those flights are demanding as well. On top of the people that they took away originally that we used to have, and this extra person who did not show up for that flight, that we have to do without, that is exhausting*" (Group 2, C). Participants argued that having additional crewmembers on board would reduce their workload, which in turn would improve their subsequent rest or increase the time available for in-flight rest.

Participants' recommendations for better managing workload are summarized in Figure 5-1 under 'Strategy 2'.

5.4.3 Work environment

Participants also felt that their work environment increased fatigue, particularly aspects of their physical work environment, work resources and collegial support. Working in a pressurized cabin with lower oxygen (airflow) levels was considered fatiguing and some participants suggested that the flight crew were responsible for lower oxygen or airflow levels in the cabin. The cold environmental temperature in the galleys was thought to increase crewmembers' energy expenditure, thus contributing to their fatigue. This problem was identified as being related to the Airbus aircraft. Problems with work resources included the malfunctioning of equipment as a source of stress contributing to fatigue, and the lack of healthy food on board: "*It is rare to find a healthy meal on board and sometimes we find ourselves pushed to eat whatever there is available there to eat, and eventually that I think affects our bodies and we cannot perform, and we get tired because we ate too much […] you know all the time they [the cockpit crew] get fruit overseas and you ask yourself why don't we have fruit as cabin crew? We are the ones that are actually burning the energy most; we need healthy food on board*" (Group 2, A). Colleagues could have a negative or a positive impact. Fatigue was linked to other team members "*not pulling their weight*".

On the other hand, the benefit of having collegial support was also highlighted, with others picking up and helping when someone struggled with fatigue.

Participants' recommendations for improving the work environment are summarized in Figure 5-1 under 'Strategy 3', while supporting staff wellbeing is listed under 'Strategy 4'.

5.4.4 Company support

Across all three groups, company support was raised as an important factor affecting fatigue at work and participants pointed out several areas where they felt support was lacking and/or could be improved.

Firstly, there was a general consensus that flight crew and cabin crew are treated as two separate cultures within the company, even though cabin crew are seen as facing the same fatigue-related challenges as flight crew. Participants listed numerous examples of better conditions for flight crew with regards to rest provisions, the quality of the work environment and resources such as food in-flight: *"they can fly a maximum of 1000 hours in a year, and we don't have a limit. This is it, and then you are trying to merge two systems together, two different, to get an outcome. It doesn't work. That is why I say it's also putting systems that are not talking, not compatible. They have got more rest because there are two on and the other two off. So they will have more rest period than normal cabin crew" (Group 3, H).*

Secondly, the communication between management and cabin crew was considered an issue. This included the company informing cabin crew about delays: "*and another issue is that whenever there is a delay, they never inform us, we can stay here for 3 or 4 hours whereas the flight deck crew they know about it. We will come in fresh and by the time we start to operate we are tired because we have been sitting there for 3 or 4 hours and then, I don't know if we are not important or what, but they tend to focus on the flight deck crew. They give them* *most of the information but they don't give us anything, so that is what they need to work on as well*" (Group 2, B).

Management's lack of effort to understand the challenges that cabin crew encounter was also raised: "*In any company you should have all the role players knowing what is going on, on the other side […] what I am saying is that our management needs to know first-hand what, how fatigue affects us and it is such things that can make change more effective and quicker*" (Group 2, J).

Thirdly, several participants discussed emotional and/or physical wellbeing as factors in fatigue. Some felt that it was not easy to book off sick, while another participant found it difficult to book annual leave when needed. Some felt that the company did not provide a career path for cabin crew, while others described a lack of appreciation or recognition from the company: *"we are always on our toes and when you come down with flu or severe flu or something or a cold, they expect you to be at work [agreement from the group]. Should you book off, it is another thing [cross talk]. That's why people tend to fall asleep..." (Group 1, D).*

Lastly, a number of participants also felt that the company '*will not go the extra mile'*, such as not paying for early access to the hotel room to help increase the crews' sleep opportunity, and not prioritizing improving facilities for sleep. For example, one participant commented on the lack of facilities for cabin crew on standby at the airport: "*The facilities here at the standby room, it's non-existing. You are sitting there, if you're there in the morning there is nothing for you, if you are there after 2 o'clock in the afternoon you can't have lunch or anything else because the cafeteria closes at 2 o'clock or 1.30 somewhere there. If you are here over weekends there is absolutely no support for you*" (Group 1, E). Participants therefore suggested a clear and effective support structure to help minimize fatigue and stress and improve productivity. See 'Strategy 4' in Figure 5-1.

5.4.5 Fatigue management training

Participants rated highly the safety training they received, but felt that the fatigue management training was inadequate – an informative forum rather than actual training. Safety training was viewed as very helpful when working fatigued, because of the skills acquired to work effectively as a team. Participants therefore suggested that the company provide a fatigue management course with an assessment component that cabin crew are required to pass: "*Simple, I think instead of a lot of the courses that the company is running that must start to introduce a fatigue management course, to make sure that every crew member, maybe once goes into that course. Instead of [inaudible] all these other courses, but I think it is the time now the company to start this an important thing, fatigue management, it must be a course that a crew member should pass [inaudible] must be trained about fatigue management*" (Group 2, G). Ab initio training (the initial training that cabin crew undergo) was strongly supported for cabin crew and all relevant personnel, including the company's medical staff and managers. Participants' recommendations for improving fatigue management training are included in Figure 5-1 under 'Strategy 5'.

5.4.6 Self-management of fatigue

When asked about managing their fatigue at home and at work, participants not only talked about the strategies they utilize, but also shared personal views on this topic. Fatigue management was viewed as a shared responsibility between the company and cabin crew, but they also indicated that the management of fatigue was under-estimated, or '*easier said than done*'. They also highlighted the need for a work-life balance: "*Just everyday life, you also are trying to keep a balance in your life, trying to, as a crew member, trying to have a normal life at home, whereas you also have your responsibilities towards your family and your friends and you are trying to keep up with the housework and cooking and it adds up and also basically you need your rest for your flights as well, so it takes up a lot of time*" (Group 3, B).

Sleep was the primary strategy utilized for managing fatigue at home, at work and on layover. Participants also talked about taking naps in preparation for a flight, in flight, in the car before driving home and/or at home upon arrival following an international flight: "*Some people sit and sleep in the car park for a while just to get over that very, very tiredness you know until they can safely drive home because not all of us stay close*" (Group 1, B). Having better standby provisions at the airport would also be beneficial for taking naps.

Strategies for promoting sleep included the use of sleeping aids such as drinking hot milk, listening to classical music, reading before bed, taking a sleeping tablet or consuming alcohol, and creating a sleep conducive environment by turning one's phone off, keeping noise to a minimum, darkening the room, and/or sleeping with an electric blanket on. Exercise before sleep was also considered beneficial for promoting sleep.

Strategies for keeping alert at work included keeping busy, making conversation, drinking plenty of water and caffeinated beverages. Receiving support from colleagues was also considered helpful. In addition, participants talked about the benefits of having a healthy lifestyle, including regular exercise and a healthy diet, to help manage their fatigue but acknowledged that this in itself was not sufficient. Participants' recommendations for improving cabin crews' self-management of fatigue are listed in Figure 5-1 under 'Strategy 6'.

5.5 Discussion

The present study has improved our understanding of cabin crew perceptions of the causes of their fatigue and how fatigue might affect safety and their job performance, particularly in the context of ULR operations.

Cabin crew participating in the present study identified a range of fatigue-related factors and made a number of suggestions for changes to help improve its management, which were summarized in six themes, namely insufficient rest, workload, work environment, company support, fatigue management training and self-managing fatigue.

The view that fatigue is inherent and inevitable due to the nature of their work is consistent with previous research (Castro et al., 2015; Nesthus et al., 2007; Ono et al., 1991; Vejvoda et al., 2001), as is the view that fatigue affects cabin crew health and wellbeing as well as safety (cabin, passenger and personal) and cabin service (Avers et al., 2011).

As well as having concerns about fatigue-related performance impairment at work, several participants reported having fallen asleep while driving home, thus increasing the risk of a motor vehicle accident (Bioulac et al., 2017). Pre-existing fatigue has been shown to increase the likelihood of the common cold, flu-like illness, and gastroenteritis (Mohren, Swaen, Kant, Borm, & Galama, 2001) Chronic short sleep, and recurrent circadian disruption resulting from shift work have each also been associated with an increased risk for obesity, diabetes mellitus, hypertension, and cardiovascular disease (Abbott, Malkani, & Zee, 2017; Itani et al., 2017). Furthermore, shift work has been associated with an increased risk of cancer (Abbott et al., 2017), and the risk of breast cancer is higher among female cabin crew compared to other shift workers (He, Anand, Ebell, Vena, & Robb, 2015).

Given these potentially serious consequences, careful consideration should be given to all sources of cabin crew fatigue to enable more effective fatigue management. While the physiological causes of fatigue are sleep loss and circadian disruption (Nesthus et al., 2007), participants also identified a range of additional contributing factors at work and outside of work, including: insufficient rest, high workload, the work environment, a lack of company support and insufficient fatigue management training. Most of these factors have been identified previously (Avers, King, et al., 2009; Avers et al., 2011; Bergman & Gillberg, 2015;

Castro et al., 2015; MacDonald et al., 2003; Ono et al., 1991; Wahlstedt, Lindgren, Norbäck, Wieslander, & Runeson, 2010). However, the present study also highlights the importance of sufficient rest not only for obtaining adequate recovery sleep but also for achieving a work-life balance. It also highlights the need for company support to assist cabin crew with fatigue management.

5.5.1 The importance of sufficient rest for a work-life balance

Participants highlighted the need for a work/life balance, but that it could be difficult to allocate adequate time for rest and recovery as well as for family responsibilities, domestic tasks, social activities, community commitments, studying, and/or maintaining hobbies and there was generally a trade-off between sleep and other activities. Both male and female participants indicated that they would attend to family responsibilities and domestic tasks when at home during the day, suggesting that this issue is not gender-specific, but rather is driven by the nature of their work. Other studies have shown that long work hours and/or family responsibilities are associated with obtaining insufficient sleep, irrespective of gender (Barnes, Wagner, & Ghumman, 2012; Skinner & Dorrian, 2015). Furthermore, shift workers are more likely to report difficulties combining work and life in comparison to day workers, particularly when work characteristics include minimum rest opportunities between periods of work, night shifts or weekend work (Karhula et al., 2017). The work schedules of cabin crew flying long haul and ULR include all these characteristics, as well as frequent time zone changes. One study based on subjective sleepiness ratings suggests that cabin crew require an additional recovery day beyond the two needed for regular daytime workers and shift workers (Åkerstedt, Kecklund, Gillberg, Lowden, & Axelsson, 2000). Although fatigue risk management focuses specifically on safety, ideally it should also facilitate a work-life balance in support of employees' health and wellbeing, since "there is more to life than work and sleep" (Costa, 2004; Gander, Hartley, et al., 2011; Lerman et al., 2012) .

Participants in the present study indicated that due to competing time demands, their families could become a source of stress at home. In a study with train drivers working shift work, receiving family support was highlighted as the most important factor in the successful management of fatigue, although the train drivers felt that family members often did not have a good understanding of shift work and fatigue (Holland, 2006). There is evidence that involving family members in fatigue management training, or providing them with take-home resources can be valuable (Lerman et al., 2012), and that the long-term value of training may be increased when there is ongoing support and reinforcement at home (Kerin & Aguirre, 2005). This aspect was therefore added to Figure 5-1 under Strategy 5.

In the present study, there was a strong consensus that rostering was not managed properly and that company support was inadequate. Where employees are dissatisfied with current rostering or other management and organisational issues, the effectiveness of fatigue management training may be reduced (Kerin & Aguirre, 2005). On the other hand, fatigue management training can improve employees' understanding and perception of the rostering, the challenges associated with working irregular hours (Kerin & Aguirre, 2005), and ameliorate any misconceptions about fatigue. Importantly, all personnel within an organisation need to understand that rostering alone cannot eliminate fatigue and should not be an organisation's only fatigue management strategy (International Civil Aviation Organization, 2016). It is therefore recommended that fatigue management training for cabin crew is evidence-based, requires assessment, and is given priority within an airline to not only educate cabin crew, but also provide a communication forum where cabin crew can share their experiences, voice any concerns and feel listened to (Gander, Marshall, Bolger, & Girling, 2005).

5.5.2 The importance of company support

Taking a safety management systems approach, fatigue risk management focusses on the conditions under which individuals work that could give rise to fatigue-related errors. This also includes the working conditions that can influence the fatigue levels of crewmembers, such as the quality of rest facilities and availability of support staff (International Civil Aviation Organization, 2016). In the present study, there was a perceived lack of company support in terms of the provision of standby facilities at the airport, the quality of cabin crew rest facilities, the ability to take sick leave and annual leave, the quality of communication from management regarding operational issues such as flight delays, as well as management's engagement with cabin crew in general. Participants also considered the fatigue-related provisions for flight crew better than for cabin crew, even though cabin crew were seen as facing the same fatigue-related challenges.

Studies have shown that employees' perceived organisational support, which to a large extent is influenced by their working conditions (Kurtessis et al., 2017; Rhoades & Eisenberger, 2002), is positively correlated with safety-related behaviour, including upward safety communication (Hofmann & Morgeson, 1999; Kath, Marks, & Ranney, 2010). Hofmann and Morgeson (Hofmann & Morgeson, 1999) suggest that employees who perceive their company as caring for their wellbeing will more easily raise any safety concerns with their managers. In FRMSs, voluntary fatigue reporting by crewmembers is an essential source of fatigue monitoring data and should empower personnel to propose preventive and corrective actions for any fatigue-related issues (International Civil Aviation Organization, 2016). In turn, management must provide feedback to their employees regarding any changes made in response to fatigue reports received (International Civil

Aviation Organization, 2016). This form of communication should also improve crews' perceptions of organisational support and communication with management.

Furthermore, all personnel with direct or indirect influence on cabin crews' work, including senior management, need to have an appropriate understanding of fatigue through participation in fatigue management training programs (International Air Transport Association et al., 2015). Making crewmembers aware of management's engagement in all fatigue management activities may enhance cabin crews' perception of company support.

5.6 Study limitations

Although it is possible that participants self-selected into the study because fatigue is a major concern for them, the present findings corroborate previous research on cabin crew fatigue (Avers, King, et al., 2009; Avers et al., 2011; Castro et al., 2015; Holcomb et al., 2009; Lowden & Åkerstedt, 1998b, 1999; MacDonald et al., 2003; Nesthus et al., 2007; Ono et al., 1991), suggesting that participating cabin crew were not suffering considerably more from fatigue than their colleagues. Each group tended to reach consensus about the issues even though every effort was made to ensure that all participants had the opportunity to be heard.

It should also be noted that 73% of the participants were male, whereas the proportion of male cabin crew at this airline was about 34% at the time of the study. It is therefore possible that the participants in this study are not entirely representative of their work force. Nevertheless, the richness of the conversation confirmed the usefulness of the focus group approach, which does not aim to provide a representative view.

Due the qualitative nature of the study, the researcher's views and experience of fatigue inevitably influenced all aspects of the study which shaped the present findings.

Additional research may involve surveying cabin crew across the whole airline on the extent of their agreement/disagreement with the views raised in the present study (Gander, Mangie, Phillips, Santos-Fernández, & Wu, 2018).

Despite these limitations, the study findings contribute to an increased understanding of the causes and consequences of cabin crew fatigue. Many of the key factors contributing to cabin crew fatigue that were identified in the present study have been reported previously (Avers, King, et al., 2009; Avers et al., 2011; Bergman & Gillberg, 2015; Castro et al., 2015; MacDonald et al., 2003; Ono et al., 1991; Wahlstedt et al., 2010). However, unlike previous studies, cabin crew in this study all had experience with ULR flights, for which FRMS processes were put in place by the airline to manage the associated fatigue risk. Nevertheless, they indicated that the management of fatigue was '*easier said than done*', highlighting that sufficient rest was not only needed for obtaining adequate recovery sleep, but also for achieving a work-life balance. In addition, they also highlighted the importance of company support needed for improving the fatigue risk management of cabin crew.

5.7 Recommendations

Based on the present findings, it is recommended that airline operators consider the importance of sufficient rest for adequate recovery and for facilitating a work-life balance in support of employees' health and wellbeing. It is also recommended that airline operators consider the importance of company support, in the form of fatigue-related processes and resources, effective communication and management's engagement with cabin crew in general. Fatigue management training and non-punitive fatigue reporting, both essential components of an FRMS, can ameliorate these gaps, in conjunction with the other fatigue risk mitigation strategies identified for improving cabin crews' safety and service, and health and wellbeing.

CHAPTER 6 DISCUSSION

This thesis aimed to evaluate the current status of, and future needs for FRMS for cabin crew. This chapter considers the findings from new research presented in Chapters 3-5 in the context of ICAO's FRMS framework (International Civil Aviation Organization, 2016), Safety Management Systems (SMS) theory (International Civil Aviation Organization, 2013; Maurino, 2017), as well as current Occupational Health and Safety (OHS) legislation (Health and Safety Executive, 2013; Safe Work Australia, 2018; Worksafe New Zealand, 2015). The chapter highlights what currently works for cabin crew and the gaps that this research has identified. The findings are directly relevant to two components of an FRMS, namely the fatigue risk management processes and the promotion processes.

The chapter concludes with recommendations for improvements, and suggestions for future research.

6.1 Fatigue risk management processes

As described in Chapter 1 (Section 1.9.2.1), fatigue risk management processes are data-driven and form a closed process loop consisting of four steps: 1) monitoring of fatigue levels; 2) identifying situations in which fatigue may be a hazard; 3) assessing the level of risk associated with a fatigue hazard; and 4) mitigating the fatigue risk where warranted (see Figure 1-5). Ongoing monitoring is necessary to evaluate the effectiveness of introduced fatigue mitigations, as well as for identifying any new fatigue hazards (International Civil Aviation Organization, 2016).

The following sections consider the study findings in the context of each of these four steps.

6.1.1 Sources of data for monitoring cabin crew fatigue

Data for the FRMS process loop come from a variety of sources. Monitoring crewmembers' sleep, fatigue and performance, as in the present study, is resource intensive and time-consuming compared to routinely collected data such as voluntary fatigue reports or monitoring rostered versus worked duties. However, crewmember monitoring studies are recommended when fatigue risk is likely to be high or is difficult to estimate, for example in a new operation. The ULR validation study described in Chapter 3 was designed to evaluate the effects of the new JNB-JFK-JNB ULR trip on cabin crew sleep, fatigue, performance, and post-trip recovery. It demonstrated that the measures recommended for monitoring flight crew (actigraphy, sleep/duty diaries and PVT), are feasible for use with cabin crew. However, compared to the companion study with flight crew on the JNB-JFK-JNB ULR trip (Signal et al., 2014), the response rate and completion rate with cabin crew were lower.

Multiple factors may have influenced the motivation of cabin crew to participate. Cabin crew in the focus group study felt that there was a lack of company support in the form of fatigue-related processes and resources. Drawing on social exchange theory (Cropanzano & Mitchell, 2005), perceived organisational support has been shown to evoke a reciprocal response from employees, including the motivation to participate in proactive and extra-role safety behaviours (Didla, Mearns, & Flin, 2009; Kurtessis et al., 2017; Reader, Mearns, Lopes, & Kuha, 2017; Rhoades & Eisenberger, 2002). Recurrent fatigue management training could strengthen crewmembers' understanding of their role and that of the company in the FRMS, and increase their willingness to participate in fatigue monitoring studies (International Civil Aviation Organization, 2016).

The usefulness of the PVT as a measure of fatigue-related changes in cabin crew performance needs careful consideration. Distractions in the testing environment, and completion of the PVT in a busy cabin are likely to have contributed to the slower pre-flight performance and large variability observed in subsequent tests, when compared to flight crew. Taking into account the logistical challenges associated with obtaining reliable PVT data in this occupational group, and the additional burden this test places on busy cabin crew, it is debatable whether PVT data add worthwhile information for the evaluation of cabin crew fatigue risk.

In addition, no significant associations were found between sleep/wake history and PVT performance at TOD, corroborating findings from a study using combined datasets from four studies including data from 237 flight crew on 730 long range and ultra-long range flights (Gander et al., 2015). These authors also raised the question as to whether the PVT is a sensitive measure of fatigue-related impairment in flight crew. Psychomotor vigilance is only one of many aspects of performance affected by sleep loss, and how an individual cabin crewmember's PVT performance relates to team performance is not known. One laboratory-based study showed that both accuracy and processing time on an interdependent decision-making task were more affected by fatigue when completed individually than when completed in a team (of four) (Baranski et al., 2007).

Cabin crew in the focus group study (Chapter 5) reported that working with colleagues could have a positive impact on fatigue, with others picking up and helping when someone struggled with fatigue. Conversely, other team members "not pulling their weight" was thought to have a negative impact on fatigue, presumably by adding to the existing workload. As demonstrated in Chapter 4, workload is a significant factor contributing to cabin crew fatigue on ULR flights and the ongoing monitoring of workload is therefore warranted. This can be achieved by including an appropriate workload question in fatigue reports, which form an essential component of FRMS, and by ensuring that in future fatigue–related studies in cabin crew, measures of workload are included.

The focus group study presented in Chapter 5 demonstrates the value of including qualitative data in an FRMS. Compared to quantitative data, essential for generating safety performance indicators (SPIs), qualitative data can provide richer and more in-depth contextual information and identify issues and concerns not readily identified using quantitative methods. Fatigue report forms usually include space for contextual information relating to the incident. However, crewmembers are typically instructed to complete the form succinctly and the analysis of fatigue reports tends to focus on the classification of incidents and trends, so additional information included in the narrative may be underutilized (Hayes & Maslen, 2015). In addition, not all fatigue-related experiences at work result in crewmembers filing a fatigue report, so deficiencies in organisational processes that could eventually lead to a hazardous situation may go undetected (Hayes & Maslen, 2015; International Civil Aviation Organization, 2013).

As demonstrated in Chapter 5, focus groups are a particularly useful method in this context because they enable crewmembers to share their views and experiences (negative as well as positive), raise any concerns they may have, as well as offering ideas for possible solutions. They also communicate to the crewmembers that their feedback is valued. Airlines can easily include occasional focus groups as part of their FRMS (Flight Safety Foundation, 2005a), for example as part of an evaluation of the fatigue risk mitigations on a newly introduced route. However, to obtain good quality results, an experienced group facilitator is required to help ensure that all participants in the group are being heard, and subsequent data analysis should follow a rigorous, systematic approach (Braun & Clarke, 2013).

6.1.2 Fatigue hazard identification based on the study findings

Fatigue hazards associated with ULR operations have previously been identified for flight crew, based on the scientific principles described in Chapter 1 and operational experience

(Flight Safety Foundation, 2003, 2005b). The long flight and duty times can lead to sleep loss, extended wakefulness, time-on-task fatigue, and also likely require crew to work during adverse times in the circadian body clock cycle. Circadian disruption resulting from rapid time zone changes and adaptation to the layover time zone will also influence crewmembers' functioning and ability to sleep on the inbound flight, as well as their rate of recovery post-trip. The extent of sleep loss and circadian disruption is modulated by the timing of flights and layovers relative to a crewmember's circadian body clock time (International Civil Aviation Organization, 2016).

However, the present research with cabin crew also highlights the importance of considering workload, the cumulative effects of fatigue across the entire ULR trip, and the context of the ULR trip in the entire roster worked.

6.1.2.1 Workload

The workload analyses (Chapter 4) showed that on the JNB-JFK-JNB ULR flights, higher perceived workload was associated with more PVT lapses, and higher sleepiness and fatigue ratings at top-of-descent (TOD). Furthermore, the findings suggest that subjective sleepiness at TOD was more affected by perceived workload than by the duration of prior wakefulness, and that PVT performance was affected by perceived workload, but not by prior in-flight sleep history. The analyses also showed that, on average, physical demands contributed the most to cabin crews' perceived workload on these ULR flights, consistent with reports from previous cabin crew studies (Castro et al., 2015; Glitsch et al., 2007; Nesthus et al., 2007).

Cabin crew in the focus group study (Chapter 5) also considered workload to be a key factor contributing to cabin crew fatigue, particularly on flights operating with minimum crew, or with a shortage of crew as a result of crewmembers being sick, when the delivery of service to passengers was already under time pressure.

High physical workload and high work demands have previously been shown to predict disturbed sleep, with high work demands also potentially reducing sleep time because of the need to 'unwind' after a work period (Åkerstedt et al., 2002). This is an important consideration for the scheduling of in-flight rest breaks for sleep on LR and ULR flights, as cabin crews' workload may reduce the recuperative value of subsequent sleep. For sleep at home, flow-on effects from prior duties with high workload could also reduce the recuperative value of recovery sleep (Åkerstedt et al., 2002).

Compared to the workload of flight crew, the higher physical activity associated with cabin crews' workload is also expected to exacerbate any fatiguing effects of mild hypoxia, resulting from working in a pressurized cabin equivalent to 6000-8000 feet above sea level, particularly during very long flights (Aerospace Medical Association et al., 2008; Muhm et al., 2007; Smith, 2007). Indeed, cabin crew in the focus group study (Chapter 5) attributed their fatigue in part to working in a pressurized cabin.

6.1.2.2 Cumulative effects of fatigue across the ULR trip

The ULR validation study (Chapter 3) found that the highest fatigue levels were not observed on the longer ULR flight, but during the latter part of the shorter inbound flight. Possible contributing factors include the cumulative effects of sleep loss across the trip, and the timing of the flight relative to the circadian body clock cycle.

The amount of sleep obtained on pre-trip baseline days was highly variable and averaged only 6.5 hours, less than the 7-9 hours recommended for maintaining optimal functioning and health (Hirshkowitz et al., 2015). On average, 33 minutes more sleep was obtained in the last 24 hours pre-trip, but total sleep on this day also varied widely between individuals.

On the outbound flight, which spanned the domicile night, cabin crews' sleep was restricted to an average of 3.6 hours sleep (range 1.6 – 5.1 hours). While they obtained on average 69 minutes more sleep during the first 24 hours of the layover compared to pre-trip baseline days, total sleep did not differ from baseline in the last 24 hours. Additional sleep loss on the inbound flight (average 2.9 hours, range 1.6 – 4.3 hours) may also have contributed to the high level of fatigue at the end of the ULR trip.

In addition, the inbound flight's local 8am arrival time may also have contributed to the cumulative effects of the ULR trip on cabin crew fatigue. Considering most crewmembers had shifted their second night's layover sleep to the local night, the circadian timing of arrival for those crewmembers may have occurred closer to the window of circadian low (2-6am). Irrespective of any circadian adaptation during the layover, previous analyses using a combined dataset of 4-pilot crews flying both long-haul and ULR flights showed that subjective sleepiness and fatigue at TOD were significantly higher on flights arriving between 06:00 – 09:59 in comparison to flights arriving later, after controlling for in-flight sleep/wake history (Gander et al., 2015) and flight duration (Gander, Mulrine, van den Berg, Smith, Signal, et al., 2014). Furthermore, pilots' PVT performance at TOD was significantly slower on flights arriving between 02:00-09:59 in comparison to flights arriving in the afternoon (14:00-17:59). Thus, for cabin crew monitored on the JNB-JFK-JNB ULR trip, highest fatigue levels are expected to occur near the end of the trip, due to the combined effects of cumulative sleep loss across the trip and adverse circadian time of arrival.

6.1.2.3 Context of the ULR trip in the roster worked

The cabin crew who participated in the present studies worked in a much broader range of flight operations, including short haul, than the flight crew at the same airline, who worked predominantly in ULR and long range operations (Capt. W. Serfontein, personal communication, 16 April 2019).

Cabin crew in the focus group study (Chapter 5) raised the cumulative effects of the roster as an important fatigue factor, in terms of the combination of successive flights, and the duration of rest breaks. They indicated that due to competing time demands at home, two days off – such as before to the ULR trip – was not considered adequate for recovery. This finding is supported by a previous study based on subjective sleepiness ratings, which suggests that cabin crew require an additional recovery day beyond the two needed for regular daytime workers and shift workers (Åkerstedt et al., 2000).

6.1.2.4 Fatigue as a compound hazard

ICAO's FRMS requirements solely focus on improving safety. However, in the context of SMS, fatigue can be viewed as a compound hazard, in that it simultaneously affects safety and health (International Civil Aviation Organization, 2013).

Cabin crew in the focus group study reported that being fatigued increased the likelihood of getting sick and/or becoming unfit to fly as a result of ill-health. This notion corroborates findings from a large population-based survey, which showed that pre-existing fatigue increased the likelihood of the common cold, flu-like illness, and gastroenteritis (Mohren et al., 2001) and that the prevalence of these common infections was higher among shift workers than day workers (Mohren et al., 2002). In addition, an experimental study demonstrated that chronic short sleep is associated with an increased susceptibility to the common cold (Prather et al., 2015).

Susceptibility to viral infections also appears to depend on the circadian timing of exposure, which, in mice, was shown to be greater during their rest phase than during their active phase (Zhuang, Rambhatla, Lai, & McKeating, 2017). Cabin crew may therefore be at a greater risk of viral infections when working during their biological night.

Cabin crew in the focus group study also talked about weight gain as a consequence of fatigue. Chronic short sleep, and recurrent circadian disruption resulting from shift work have both been associated with an increased risk for obesity, diabetes mellitus, hypertension, and cardiovascular disease (Abbott et al., 2017; Itani et al., 2017). Furthermore, shift work has been associated with an increased risk of some cancers (Abbott et al., 2017), and the risk of breast cancer is higher among female cabin crew than other shift workers (He et al., 2015).

Since fatigue is a compound hazard, the immediate and long-term consequences of recurrent sleep restriction and circadian disruption on health and well-being should ideally be considered as part of an airline's risk management approach. However, in commercial aviation, different legislative and regulatory frameworks are often used to manage safety versus health risks. In several countries, including New Zealand, Australia, and the United Kingdom, the occupational health and safety (OHS) legislation also describes a four-step process for managing risks, which maps to the FRMS approach (Health and Safety Executive, 2013; Safe Work Australia, 2018; Worksafe New Zealand, 2015) and requires policy and documentation, risk management training for all relevant personnel, and quality assurance. The New Zealand and Australian OHS legislation also specifically identifies fatigue as a cause of hazards.

Since the effects of fatigue are wide-ranging from operational safety to health-related problems, fatigue risk management may be optimized if the two systems managing these were linked. Rather than FRMS and OHS operating in parallel, some of their components could overlap to ensure effective collaboration and communication. For example, a representative from the Health and Safety committee could also serve as a member on the FSAG committee[16], and vice versa. Also, fatigue management training could be extended to

[16] Fatigue Safety Action Group (see Chapter 1, Section 1.9.2.1)

cover the adverse health consequences of chronic sleep restriction and recurrent circadian disruption, further educating cabin crew about the importance of obtaining sufficient sleep as often as possible. It is also important that the company's managers and medical staff understand these negative health consequences, in relation to absenteeism, productivity, and costs, to ensure that the best possible mitigations are implemented (Costa, 2010).

Although ICAO suggest in their SMS guidance that a compound hazard such as fatigue may be managed more effectively through an integrated risk mitigation system (International Civil Aviation Organization, 2013), their FRMS guidance at present focusses solely on operational safety. Thus, there is a significant gap in fatigue risk management for cabin crew. Information about methods and processes for linking FRMS and OHS systems in an effective manner is non-existent and an issue that requires thought and development.

6.1.3 Fatigue risk assessment

Assessment of the operational risk associated with fatigue hazards should be based on the expected level of fatigue combined with the likelihood and severity of the consequences associated with that level of fatigue (International Civil Aviation Organization, 2016; Tritschler, 2015).

On the JNB-JFK-JNB ULR trip, cabin crew fatigue levels were higher when they had been awake longer at TOD and were highest on the inbound flight at TOD and after landing (Chapter 3). As discussed in the previous section, this could be attributed to incomplete recovery from the previous trip, the cumulative sleep debt accrued across the ULR trip, the extended wakefulness experienced in flight, the timing of the flight's arrival relative to the crewmembers' body clock time, as well as the influence of perceived workload in flight.

Although their comments were not specific to the ULR trip, cabin crew in the focus group study reported that mistakes in everyday safety-related tasks, such as disarming doors, do happen as a result of decreased alertness, forgetfulness, and performance changes. They also reported dozing off (i.e. falling sleep uncontrollably) while seated during the landing phase (Figure S-1, Appendix S). Even though it was said that, due to their safety training and working as part of a team, cabin crew are able to handle emergency situations when fatigued, they were nevertheless worried about safety being compromised, and the prospect of having to conduct an evacuation under high levels of fatigue was raised as a concern.

In addition to having concerns about fatigue-related safety at work, several participants also reported having fallen asleep while driving home. Drowsy driving increases the risk of a motor vehicle accident (Bioulac et al., 2017) and for cabin crew, the likelihood of this occurring is expected to be greater when arriving back from long-haul and ULR flights that spanned the crewmembers' biological night, particularly if little or no in-flight sleep was obtained.

6.1.4 Evaluation of fatigue mitigations for cabin crew

The fatigue mitigations that were put in place for cabin crew operating the JNB-JFK-JNB ULR trip were based on existing flight crew data and ULR scheduling practices for flight crew (Flight Safety Foundation, 2003, 2005b). These included a) scheduled in-flight rest periods in crew rest facilities, b) a two-day layover allowing for two major sleep opportunities prior to the inbound flight, and c) protected time off-duty before and after the ULR trip to assist with preparation for the trip and subsequent recovery. The scheduling of free days before and after the ULR trip were also intended to facilitate re-acclimatization to domicile time before starting the next duty period (Flight Safety Foundation, 2005b). Since it was predicted that the fatigue hazards would be the same for both crews, the fatigue mitigations for cabin crew flying the JNB-JFK-JNB ULR trip mirrored those for flight crew.

However, the effectiveness of these mitigations may differ between cabin crew and flight crew.

6.1.4.1 Scheduled in-flight rest for sleep

The scheduling of in-flight rest breaks for sleep in crew rest facilities is the primary fatigue mitigation during ULR flights. The effectiveness of in-flight rest breaks as a mitigation for fatigue depends on the amount and the quality of sleep that crewmembers are able to obtain in flight (Signal et al., 2005). This is, in turn, dependent on operational factors such as the flight's local departure time, flight duration, and timing of in-flight rest breaks (Gander, Mulrine, van den Berg, Smith, Signal, et al., 2014; Signal, Gander, et al., 2013; van den Berg, Wu, & Gander, 2016), as well as environmental factors such as turbulence, noise, and comfort (Pascoe et al., 1994; Zaslona et al., 2018).

Flight crews' and cabin crews' in-flight sleep is generally affected by the same factors. However, due to the requirement for all cabin crew to be awake for meal services, they had on average 33% of the flight available for rest, compared to 44% for flight crew operating this same route (Signal et al., 2014) (see Table W-1, Appendix W).

For both flight and cabin crew, the airline recommended two rest breaks per crewmember on the outbound flight, but made no recommendation about the allocation of breaks on the inbound flight. Consequently, more than half of the cabin crew had a single break on the inbound flight. Arguably, when breaks are split the additional time required to prepare for sleep, and subsequent work, could impact on the amount of sleep that cabin crew are able to obtain in flight. Although the splitting of breaks did not appear better or worse compared to a single break in terms of the total amount of sleep obtained on the inbound flight, cabin crew in the focus group study favoured having two shorter breaks rather than one long break, to enable at least one break to coincide with a more favourable circadian time for sleep. This is consistent with recommendations from other groups (Flight Safety Foundation, 2005a; Robertson et al., 1997). An additional benefit of the split break pattern is that it minimizes the duration of time awake at TOD, confirmed for cabin crew in the present study by the finding that a longer duration of wakefulness (but not prior sleep) was associated with increased fatigue and sleepiness at TOD.

With regard to the quality of in-flight sleep, the regulatory requirements for cabin crew on board rest facilities are often less stringent than for flight crew (Banks et al., 2009). The flight crew rest facility, located immediately behind the flight deck, contained two bunks. In contrast, the cabin crew rest facilities had seven bunks, located below the main cabin at the rear of the aircraft.

Cabin crew in the focus group study raised several issues with the crew rest facilities affecting their in-flight sleep, including the temperature being too hot or too cold, noise from flushing toilets and the septic tank pump, the exit light being too bright, as well as the comfort of the bunk itself. A number of crewmembers felt that the company was not making sufficient effort to improve cabin crews' rest facilities and this contributed to a perceived lack of company support.

In addition to the scheduled in-flight rest breaks, almost half of the cabin crew made use of the optional 40-minute seat rest available on the outbound ULR flight. Of those who used the seat rest, 64% obtained some sleep. Cabin crew in the focus group study, however, raised concerns about the designated seat being in Economy class, making it less conducive to sleep. They stressed the importance of being able to sit away from passengers during their rest opportunity. One possible solution to this would be to block off the last row of seats on one side of the aircraft cabin, but this would have financial implications for the airline.

Potentially, the workload of cabin crew could also affect the recuperative value of their in-flight sleep. Compared to flight crew, cabin crews' workload is physically more demanding (Avers, King, et al., 2009; Damos et al., 2013; Glitsch et al., 2007; Hagihara et al., 2001; Samel et al., 2002; Williams, 2003). High work demands, and the stress associated with this, are expected to increase the time needed to unwind, which, in turn, can impact on subsequent sleep (Åkerstedt et al., 2002). In the present study however, no association was found between perceived workload and the total amount of in-flight sleep that cabin crew were able to obtain (Chapter 4). This is most likely due to the way perceived workload was assessed. Cabin crew were asked to complete the raw TLX at the end of the flight and consider their workload retrospectively for the entire flight. Variations in workload during the flight were therefore not assessed. In future studies, the inclusion of a workload rating immediately preceding in-flight rest would be useful for evaluating the relationship between cabin crews' workload and subsequent in-flight sleep.

Cabin crew in the focus group study argued that reducing their workload (by increasing the number of crew) would improve subsequent rest or increase the time available for in-flight rest. Noteworthy is that South African Airways, who normally operates the A340-600 with 12 crewmembers, added a further two crewmembers to assist with service on this ULR operation (Capt. W. Serfontein, personal communication, 28 January 2014).

6.1.4.2 Two-day layover

To facilitate recovery from sleep loss and fatigue accrued across the westward outbound flight, and preparation for the inbound flight, cabin crew were provided with protected time off-duty during an approximate 48-hour layover that included two local nights. They were advised to stay on domicile time to minimize circadian adaptation to the local layover time and assist with faster recovery post-trip at home.

During the first 24 hours of the layover, the majority (85.3%) of cabin crew slept more than once (see Figure 3-1). The domicile arrival time (median 12:41 JNB time, 06:41 New York time) facilitated sleeping soon after arrival, during the 'afternoon nap window'. The timing of crewmembers' main sleep on this day was mixed, either coinciding primarily with their biological night, or with the local night, but on average they obtained 69 minutes more sleep than on pre-trip 'baseline' days. In contrast, during the last 24 hours of the layover, the average amount of sleep did not differ from baseline. Most crewmembers only slept once, and most delayed their sleep to coincide with the local night.

A preference for sleep during the layover's local night has been observed previously among aircrew (Holmes et al., 2012; Kandelaars, Fletcher, Eitzen, Roach, & Dawson, 2006; Lowden & Åkerstedt, 1998b, 1999; Signal et al., 2014). A previous study involving 19 cabin crew on a westward outbound long-haul trip crossing 9 time zones compared the recovery value of sleeping on domicile versus local time during a two-day layover (Lowden & Åkerstedt, 1998a). The within-subjects comparison showed that by staying on domicile time, layover sleep was less disturbed, and mean daily sleepiness ratings, and ratings of jet lag feelings were lower by the end of the layover, in comparison to adopting local sleep times. However, post-trip, ratings of jet lag feelings did not differ on average between the two layover sleep strategies (Lowden & Åkerstedt, 1998a).

In the present study, the inbound JFK-JNB flight departed mid-morning local time (median = 11:15), or 17:15 domicile time. This start time caused sleep to be truncated on the morning of the inbound flight for the majority of cabin crew, as a result of delaying their second night's sleep to local night. Pre-flight napping was not feasible for most crewmembers due to the relatively short period of time between waking and sign-on, coupled with the adverse circadian phase for sleep.

A recent study using combined datasets from 6 studies monitoring flight crew fatigue on long-haul and ULR trips with 1-3 day layovers (Cosgrave, Wu, van den Berg, Signal, & Gander, 2018) found that the total amount of sleep in the last 24 hours of the layover was greatest for inbound flights departing between 12:00-15:59 domicile time (assuming minimal adaptation to local time). In turn, a greater amount of sleep in the last 24 hours predicted lower fatigue and sleepiness ratings at the start of the inbound flight. To what extent flight crew adhered to a domicile sleep pattern during these layovers was however not investigated.

In the present study, there was considerable variability among cabin crew in their total layover sleep and the findings suggest that at least for some crewmembers, recovery following the two-day layover was incomplete. The focus group study (Chapter 5) highlighted additional factors that may have impacted on layover sleep, although these comments were not specifically related to the ULR trip.

Firstly, the minimum rest requirement between duty periods does not begin at sign-off time but starts from 'on-chocks'. Consequently, any delay at the airport reduces the crews' available time for rest. In a large-scale fatigue survey with US-based cabin crew, one of the most commonly recommended operational changes to reduce fatigue was to start the rest period on arrival at the layover hotel (Avers, King, et al., 2009). In practise, it may be more feasible to start the rest period from sign-off time (approximately 30 minutes after landing).

Secondly, issues relating to layover hotels were identified, including proximity to the airport, amenities in the area and the time required to access these, as well as noise disturbance from traffic, construction, and/or adjacent night clubs. Inside the hotel, disturbances from other hotel guests, and/or housekeeping were also common. Arriving before check-in time and having to wait for a room also shortens the available time for sleep and some crewmembers felt that the company would not 'go the extra mile' to pay for early access to the hotel room. Poor communication about expected flight delays was identified as precluding any additional rest on the day of departure, since crewmembers are expected to be ready when called. In turn, these factors contributed to a perceived lack of company support.

On the other hand, crewmembers also indicated that the layover destination could influence the amount of time spent on sleep versus recreation, thus highlighting the need for recurrent fatigue management training to re-iterate the importance of prioritizing sleep.

6.1.4.3 Protected time off-duty for sleep and recovery at home

As noted previously, to assist cabin crew with preparation for the ULR trip, they were rostered to be free of duty for two days (including three local nights) prior the ULR trip. To allow for adequate recovery, and re-acclimatization post-trip, they were provided with four local nights at home before their next duty period.

Cabin crew in the focus group study (Chapter 5) stated that in general, they use sleep as the primary strategy for managing their fatigue, including taking naps in the car before driving home, and/or at home following an international flight, and in preparation for the next flight. They also made positive comments about having an additional day free of duty before the Johannesburg-New York ULR trip compared to the pre-duty rest requirements prior to other international trips.

Findings from the ULR validation study (Chapter 3) showed that cabin crew generally prepared well for the ULR trip, by obtaining an average of 33 minutes additional sleep in the 24 hours pre-trip compared to the two preceding ‘baseline’ days, and almost half of the participants took a pre-flight nap. However, even though cabin crew and flight crew had the same protected time off duty prior the ULR trip, cabin crew obtained on average about half an hour less sleep on each of these days compared to flight crew (Signal et al., 2014; van den

Berg, 2016). Cabin crews' sleep on pre-trip baseline days averaged 6.5 hours and varied widely between individuals (see Figure 3-1, and Appendix U, Table U-1). A number of crewmembers also had split nighttime sleep (see Figure 3-1). In addition, cabin crews' pre-flight sleepiness and fatigue ratings ranged widely before the outbound flight (see Appendix U, Tables U-2 and U-3, and Appendix V, Figures V-1 and V-2), suggesting that some crewmembers' preparation for the ULR trip was not completely effective.

There are several factors that may have impacted on cabin crews' pre-trip sleep. In the focus group study (Chapter 5), cabin crew indicated that due to competing time demands at home, there was generally a trade-off between sleep and other activities, in an attempt to fit everything into the limited time available. This issue did not appear to be gender-specific, but rather driven by the nature of their work. Other studies have also found that long work hours and/or family responsibilities are associated with obtaining insufficient sleep, irrespective of gender (Barnes et al., 2012; Skinner & Dorrian, 2015). However, shift workers are more likely to report difficulties combining work and other aspects of life in comparison to day workers, particularly when work characteristics include minimum rest opportunities between periods of work, night shifts or weekend work (Karhula et al., 2017).

Cabin crew flying long-haul and ULR face the additional challenge of recurrent jet lag. Cabin crew in the focus group study reported that circadian disruption due to time zone changes was a primary fatigue factor, and that their rest was insufficient as result of the cumulative effects of the roster. Disturbed sleep is one of the most common complaints associated with jet lag (Arendt, 2018; Graeber, Dement, Nicholson, Sasaki, & Wegmann, 1986) and the occurrence of split nighttime sleep on pre-trip days suggests that at least some crewmembers may not yet have been fully re-acclimatized.

The rate of re-acclimatization post trip is influenced by several factors, including the number of time zones crossed (Suvanto et al., 1990), how much adaptation occurred on the layover (Härmä, Laitinen, et al., 1994; Härmä, Suvanto, et al., 1994; Samel, Wegmann, Summa, & Naumann, 1991), the inbound flight's timing and direction (Cosgrave et al., 2018; Suvanto et al., 1990), the amount of sleep debt accrued by the end of the trip (Lamond, Petrilli, Dawson, & Roach, 2006; Roach et al., 2012), the timing and degree of exposure to home-based zeitgebers (day light, physical activity/exercise, meal timing, social activities) (Buxton, Lee, L'Hermite-Balériaux, Turek, & Van Cauter, 2003; Czeisler & Buxton, 2017; Suvanto, Härmä, & Lajtinen, 1993) and individual differences in tolerance to jet lag (Atkinson et al., 2014).

Personal factors may also have a role in cabin crews' recovery. In the focus group study (Chapter 5), cabin crew talked about their physical ability being stretched, and their health status influencing the amount of fatigue experienced. It was also thought that the effects of fatigue on health become more prominent with aging (see Figure S-1 in Appendix S). As described in Chapter 1, age-related changes in sleep and the circadian system are associated with a decreased tolerance to night work and jet lag (Duffy et al., 2015). However, evidence that age influences the rate of recovery following long-haul flights is mixed (Lowden & Åkerstedt, 1999; Moline, Pollak, Monk, & Lester, 1992; Suvanto et al., 1990).

As with the pre-trip days, the four local nights free of duty post-trip appeared, on average, to be adequate, given that the amount of sleep per 24 hours on post trip days 2-4 did not significantly differ from sleep on baseline days. However, on each post-trip day, the amount of sleep varied greatly within and between individuals (see Figure 3-1, and Appendix U, Table U-1), as did the post-sleep sleepiness and fatigue ratings (see Appendix U, Tables U-8 and U-9), which suggests that some crewmembers recovered more slowly than others (Chapter 3).

To help improve recovery at home, cabin crew in the focus group study suggested that rostering practices could be changed to optimize time for rest. Although a perfect roster does not exist when work schedules overlap with individuals' normal sleep time, changes to modifiable roster characteristics should be considered in order to reduce the cumulative sleep loss and fatigue across the roster worked, as well as facilitating a work-life balance in support of employees' health and well-being. Cabin crew in the focus group study suggested that the maximizing of rest breaks between duty periods could be achieved by changing the combination of flights, reducing the number of successive 'hectic' flights to reduce their cumulative effects, shortening very long turnaround times to reduce long duty days, and by reducing the number of work hours per month. This highlights the importance of including rostering personnel in recurrent fatigue management training.

Noteworthy is that preferential bidding, or the ability to choose flights in upcoming monthly work schedules, was not available to cabin crew taking part in the present studies, in contrast to flight crew, as well as cabin crew working at other airlines (Avers, Hauck, Blackwell, & Nesthus, 2009; Avers et al., 2011; British Airways, 2018). Increased flexibility or control over work hours has been associated with a greater tolerance to shift work (Barton, Smith, Totterdell, Spelten, & Folkard, 1993; Knauth & Hornberger, 2003).

Cabin crew in the focus group study talked about the benefits of having a healthy lifestyle, including regular exercise and a healthy diet, but acknowledged that this in itself was not sufficient. Education on the importance of recovery sleep at home, including information on individual differences in sleep need and recovery, would therefore be beneficial for cabin crew.

6.1.4.4 Additional mitigations recommended by cabin crew

By taking a safety management systems approach, fatigue risk management also focusses on the conditions under which individuals work that could give rise to fatigue-related errors (International Civil Aviation Organization, 2016). These also include the working conditions which can influence the fatigue levels of crewmembers, such as the quality of rest facilities, and the availability of support staff.

Cabin crew in the focus group study (Chapter 5) suggested additional mitigations to help manage their fatigue, by improving the working conditions and aspects of their physical work environment that they considered to be contributing factors to fatigue. They also expressed a need for a clear and effective support structure to help minimize fatigue and stress, and improve productivity.

Cabin crew considered that flight crew had better fatigue-related provisions, even though they face the same fatigue-related challenges as flight crew (Chapter 5). Specific issues included the lack of facilities for cabin crew on standby at the airport, the company's unwillingness to pay for early access to hotel rooms, not prioritizing the repair of crew rest facilities, poor accessibility to managers, and the limited support they offer to crew.

Issues not directly related to fatigue but affecting cabin crew's emotional and/or physical well-being were also raised, including difficulties with booking sick leave or annual leave. Some crewmembers felt that there was a lack of appreciation or recognition from the company, in line with previous findings from a large-scale fatigue survey with US-based cabin crew, in which many respondents expressed a dissatisfaction with their airline's concern for cabin crew health and well-being in favour of financial profit (Avers et al., 2011).

Working conditions are an important consideration, based on findings from a number of studies which have shown that working conditions influence employees' perception of organisational support (Kurtessis et al., 2017; Rhoades & Eisenberger, 2002). Perceived organisational support, in turn, has been shown to be positively correlated with safety-related behaviour (Hofmann & Morgeson, 1999). Furthermore, there is some evidence to suggest that adverse working conditions, including the lack of social support at work and organisational injustice are associated with future reports of sleep disturbances (Linton et al., 2015).

6.2 Promotion processes

FRMS promotion processes include two main activities, namely fatigue risk management training and FRMS communication (International Air Transport Association et al., 2015).

Effective safety communication and the sharing of fatigue-related information across the company from management to operational personnel, and vice versa, is essential for the promotion of a positive safety culture throughout the company and achieve full involvement from all relevant personnel. It includes information from the Fatigue Safety Action Group about the FRMS's safety performance and activities, as well as actions taken in response to fatigue reports received from crewmembers.

Effective safety communication, in turn, requires that everyone has an appropriate understanding of fatigue and its risks, the management thereof, and their role and responsibilities within FRMS (International Civil Aviation Organization, 2013, 2016). The training should also educate and motivate crewmembers to use personal fatigue mitigation strategies, and to report fatigue hazards at work (International Civil Aviation Organization, 2016; Kerin & Aguirre, 2005; Lerman et al., 2012).

These promotion processes are fundamental to the continuing improvement of a company's FRMS. How these processes work for cabin crew, and what could be improved is discussed next.

6.2.1 Fatigue management training

Evidence from the ULR validation study (Chapter 3) suggests that the uptake of fatigue management training was generally good. Cabin crew generally prepared well for the ULR trip. All crewmembers attempted sleep in the bunk during each scheduled in-flight rest break, and almost half made use of the optional 40-minute seat rest on the outbound flight. Post-trip, crewmembers obtained almost 1.5 hours more sleep in the first 24 hours when compared to baseline days, and 58% took a post-flight nap. On the other hand, the recommendation to stay on domicile time during the layover was not followed by the majority of cabin crew, causing sleep to be truncated for many on the morning of the inbound flight.

Cabin crew in the focus group study (Chapter 5) indicated that they viewed the management of fatigue as a shared responsibility between the company and cabin crew. In general, they use sleep as the primary strategy for managing fatigue at home, at work, and during the layover, including taking naps in preparation for a flight, in flight, in the car before driving home and/or at home upon arrival following an international flight. They also practice good sleep hygiene and utilize recommended alertness strategies at work. In addition, participants talked about the benefits of having a healthy lifestyle, including regular exercise and a healthy diet, to help manage their fatigue.

However, they also indicated that the management of fatigue was '*easier said than done'* and provided a number of reasons for this.

Firstly, they felt that the fatigue management training was inadequate - an informative forum rather than actual training. Suggestions included that the company provide a fatigue management course with an assessment component that cabin crew are required to pass. Being offered fatigue management training as part of their ab initio training (when starting out at the company) was considered beneficial. Evaluating the effectiveness of the fatigue management training can be useful for identifying any aspects of the training material that may need to be modified in order to meet the needs of the participants (Tepas, 1993).

Secondly, due to competing time demands it could be difficult to allocate adequate time for rest and recovery as well as for family responsibilities, domestic tasks, social activities, community commitments, studying, and/or maintaining hobbies**.** Cabin crews' irregular work patterns not only affect crewmembers themselves but also their families, which could become a source of stress at home. Receiving family support has previously been highlighted as the most important factor in the successful management of fatigue (Holland, 2006) and there is evidence that involving family members in fatigue management training, or providing them with take-home resources can be valuable (Lerman et al., 2012). Furthermore, the long-term value of training may be increased when there is ongoing support and reinforcement at home (Costa, 2010; Kerin & Aguirre, 2005).

Thirdly, there was a strong consensus that rostering was not managed properly and that company support was inadequate, which may have reduced the uptake of fatigue management training (Kerin & Aguirre, 2005). Recurrent fatigue management training might help change this perception and improve employees' understanding of the challenges associated with working irregular hours (Kerin & Aguirre, 2005).

A number of cabin crew had misconceptions about fatigue or reported inaccuracies, despite having received fatigue management training. For example, some suggested that the flight crew were responsible for lowering oxygen or airflow levels in the cabin, increasing their fatigue. Refresher training could help remedy these misunderstandings (Gander et al., 2005).

Cabin crew in the focus group study also indicated that the layover destination influenced choices about sleep versus other activities. Combined with the actual choices made about sleep timing in the ULR validation study, these findings suggest that recurrent training is needed to reinforce the importance of prioritising sleep, and to provide more information on the multitude of factors that influence layover sleep, including the duration of the layover, prior flight's direction, number of time zones crossed, the duration of prior wakefulness, the timing of arrival and departure, age, and social factors (Cosgrave et al., 2018; Gander, Graeber, Connell, & Gregory, 1991; Gander, Gregory, et al., 1998; Gander, Nguyen, Rosekind, & Connell, 1993; Härmä, Suvanto, et al., 1994; Kandelaars et al., 2006; Lowden & Åkerstedt, 1998a, 1998b, 1999; Roach et al., 2012; Turner, Robertson, & Spencer, 2010).

They also strongly supported that all personnel with direct or indirect influence on cabin crews' work, including the company's medical staff, and managers receive fatigue management training, as recommended in ICAO's FRMS guidelines (International Air Transport Association et al., 2015).

Additionally, recurrent fatigue management training provides crewmembers with an opportunity to share their experiences, voice any concerns and feel listened to, and is expected to keep fatigue a 'current topic' (Gander et al., 2005).

6.2.2 FRMS communication

Although cabin crew in the focus group study (Chapter 5) did not discuss the quality of management's safety communication per se, they found that management's engagement with cabin crew in general was lacking. In addition, cabin crew felt ill-informed about issues such as flight delays, and these gaps in communication contributed to a perceived lack of company support. This is an important issue to consider because, as noted previously, perceived organisational support has been shown to be positively correlated with safety-related behaviour, including upward safety communication (Hofmann & Morgeson, 1999; Kath et al., 2010).

Fatigue reporting provides essential data for the FRMS on hazards identified by cabin crew. Hofmann and Morgeson (1999) suggest that employees who perceive their company as caring for their well-being will more easily raise any safety concerns with their managers. The fatigue reporting system should empower personnel to propose preventive and corrective actions for any fatigue-related issues (International Air Transport Association et al., 2015). In addition to receiving feedback from management on any changes made in response to fatigue reports, perceptions of organisational support may also improve if crewmembers are made aware of management's engagement in *all* fatigue management activities, for example through regular newsletters, bulletins, and/or on-line forums (International Air Transport Association et al., 2015).

6.3 Summary and Recommendations

The overall aim of this research project was to evaluate the current status of an FRMS specifically for cabin crew, and to determine its future needs. Using a mixed methods approach, by combining quantitative findings from the ULR validation study (Chapters 3 and 4) and qualitative findings from the focus group study (Chapter 5), an in-depth evaluation of two key components of the FRMS framework was undertaken.

The ULR validation study (Chapter 3) demonstrates that by using mitigations mirroring those used for flight crew, cabin crew fatigue was, on average, managed effectively on the outbound ULR flight. In addition, this study demonstrates that collecting fatigue monitoring data, as for flight crew, is also feasible for cabin crew, provided that operational differences between cabin crew and flight crew are considered. However, the present research also highlights the importance of considering workload, the cumulative effects of fatigue across the entire ULR trip, and the impact of the entire roster worked, for improving the management of cabin crew fatigue associated with ULR operations, as well as for cabin crews' fatigue risk management in general.

To improve fatigue risk management for cabin crew, a number of recommendations have been proposed which largely map onto the strategies proposed by cabin crew in Chapter 5 and are included in Figure 5-1 (Chapter 5). These recommendations are summarized here.

Recommendation 1: Optimize rest to facilitate recovery and a work-life balance

Although a perfect roster does not exist when duty periods overlap with individuals' normal sleep time, changes to modifiable roster characteristics should be considered in order to reduce cumulative sleep loss and fatigue across the roster worked, as well as facilitating a work-life balance in support of employees' health and well-being. Suggested changes include:

- Starting a post-flight rest period from sign-off instead from 'on-chocks'. On layovers, consideration should be given to starting the rest period upon arrival at the hotel, or at least from sign-off time (approx. 30 minutes after landing);
- Changing the combination of flights in order to maximize rest between duty periods, decreasing the number of successive 'hectic' flights to reduce their cumulative effects, decreasing the length of layovers between short haul flights (i.e. turnaround times) to reduce long duty days, and reducing the number of work hours per month;
- Promoting the use of in-flight rest schedules on both sectors of a ULR trip to enable at least one break to coincide with a more favourable circadian time for sleep, and

reduce prolonged periods of wakefulness during the flight, through strategies such as splitting the breaks.

Recommendation 2: Improve fatigue management training

Fatigue management training is essential to ensure that crewmembers, and all other relevant personnel, understand the scientific principles that underpin FRMS, and the causes and consequences of cabin crew fatigue. Recurrent fatigue management training will reinforce the importance of attempting to obtain sufficient sleep on days off at home and on layover, and motivate crewmembers to use personal fatigue mitigation strategies, and report fatigue hazards at work (International Civil Aviation Organization, 2016; Kerin & Aguirre, 2005; Lerman et al., 2012). Furthermore, the training will help increase their understanding about why a 'perfect' roster does not exist. To improve the uptake of fatigue management training, the following should be considered:

- Providing interactive fatigue management training sessions that include an assessment component that cabin crew are required to pass;
- Evaluating the effectiveness of the fatigue management training to help determine its efficacy and identify any aspects of the training material that may need to be modified in order to meet the needs of the participants;
- Providing fatigue management training to new crewmembers (ab Initio);
- Providing refresher training sessions;
- Involving family members (e.g. spouses, partners) in fatigue management training or providing them with take-home resources;
- Providing fatigue management training to all relevant personnel, including the company's medical staff, rostering personnel, and managers.

Fatigue management training could be extended to cover the adverse health consequences of chronic sleep restriction and recurrent circadian disruption, to further educate cabin crew about the importance of obtaining sufficient sleep as often as possible. It is also important that the company's managers and medical staff understand these negative health consequences in relation to absenteeism, productivity, and costs, to ensure that the best possible countermeasures are implemented (Costa, 2010).

By strengthening crewmembers' understanding of their roles and responsibilities in an airline's FRMS through recurrent fatigue management training, their willingness to participate in fatigue monitoring studies may also increase.

Recommendation 3: Enhance perceived company support

The present research highlighted that a perceived lack of company support contributes to cabin crews' experience of fatigue. Cabin crew are seen as facing the same fatigue-related challenges as flight crew, yet the fatigue-related provisions for flight crew were considered better than those for cabin crew. To help minimize fatigue and stress, and improve productivity, cabin crew in the focus group study expressed a need for a clear and effective support structure. They also recommended improvements to their working conditions, and aspects of their physical work environment, specifically:

- Improve in-flight rest facilities for cabin crew;
- Provide ready access to the layover hotel room;
- Provide better standby provisions at the airport, particularly during the weekend;
- Support staff well-being, for exampling by linking into the company's OHS processes (see Recommendation 5 below);
- Ensure clear communication between management and cabin crew. This could be facilitated by promoting the fatigue reporting system among cabin crew during

recurrent fatigue management training. Perceptions of organisational support may also improve if crewmembers are made aware of management's engagement in *all* fatigue management activities, for example through regular newsletters, bulletins, and/or on-line forums;

- Provide an adequate work environment, including the provision of healthy food in-flight, ensuring that all equipment on board is functional, and ensuring thermal comfort in the galleys.

Improving perceived company support may also evoke a reciprocal response from employees, including the motivation to participate in fatigue monitoring studies.

Recommendation 4: Manage and monitor cabin crew workload

Workload is a significant factor contributing to cabin crew fatigue on ULR flights and the ongoing monitoring of workload is therefore warranted. This can be achieved by including an appropriate workload question in fatigue reports, which form an essential component of FRMS, and by ensuring that in future fatigue–related studies in cabin crew, measures of workload are included. Consideration should be given to the service expectations and the time available to crew for delivering these, in addition to the safety-related tasks. By ensuring appropriate staffing levels, workload would be reduced, which in turn would be expected to improve the recuperative value of subsequent rest.

Recommendation 5: Link FRMS and OHS processes for optimizing the risk management of fatigue as a compound hazard

ICAO's FRMS guidelines focus solely on improving safety. However, the present research highlights that the consequences of fatigue are twofold, affecting 1) cabin crew health and well-being and 2) safety (cabin, passenger and personal) and cabin service. Viewing fatigue as a compound hazard, the management of the fatigue-related safety risks and health risks may be optimized if FRMS and OHS can be more closely linked, or integrated (International Civil Aviation Organization, 2013). For example, a representative from the Health and Safety committee could also serve as a member on the FSAG committee, and vice versa. However, the best methods and processes for linking FRMS and OHS systems are not well understood or documented, therefore this is an area that requires further discussion and research.

6.4 Limitations

There are a number of study limitations that need to be considered when interpreting the findings.

Firstly, all data were collected from cabin crew working at South African Airways and due to operational, organizational, regulatory, and/or cultural differences, may not be representative of cabin crew working at other airlines internationally.

Secondly, the findings from the ULR validation study (Chapter 3) cannot be generalized to other ULR operations that differ in flight duration, departure times and/or arrival times, since these factors will influence how much and how well crewmembers are able to sleep at various times in flight (Gander, Mulrine, van den Berg, Smith, Signal, et al., 2014; Gander, Signal, et al., 2013; Signal, Gander, et al., 2013).

There were also limitations regarding the evaluation of cabin crews' recovery. The extent of circadian disruption and re-acclimatization could not be evaluated as part of cabin crews' recovery at home post-trip, since, for logistical and financial reasons, the ULR validation study did not include a measure of circadian phase. Instead, the timing of sleep and occurrence of split night-time sleep, were used as a proxy for circadian disruption. However other, non-physiological factors may have influenced these aspects of sleep. The inclusion of a jet lag rating, made at the same time each day (Petrie, Conaglen, Thompson, & Chamberlain, 1989; Waterhouse et al., 2000) may have benefited this study.

In addition, the variable timing at which fatigue and sleepiness ratings were made after main night-time sleeps may have limited the ability to detect differences between baseline days and post-trip days. However, asking crewmembers to rate their fatigue and sleepiness at regular intervals during each post-trip day would have increased the study burden substantially.

It is possible that some of the non-significant findings in the linear mixed model analyses, presented in Chapters 3 and 4, may be due to insufficient statistical power. Due to a lack of cabin crew ULR data, power calculations were based on flight crew ULR data. While the variability in pre-flight sleep duration and in-flight sleep duration was similar (preflight sleep: flight crew SD=96 minutes; cabin crew SD=79 minutes; in-flight sleep: flight crew mean SD=63 minutes; cabin crew SD=44 minutes on outbound, SD=50 minutes on inbound flight), the variability in TOD measures was greater among cabin crew in comparison to flight crew (KSS ratings at TOD: cabin crew SD outbound =2.0; SD inbound =1.9; flight crew mean SD=1.5; SP ratings at TOD: cabin crew SD outbound =1.7; SD inbound =1.5; flight crew mean SD=1.2; PVT response speed at TOD: cabin crew SD outbound=0.8; SD inbound=0.7; flight crew mean SD=0.6). Future studies monitoring cabin crew fatigue on ULR operations, that include these TOD measures will therefore require a larger sample size.

There are also a number of limitations associated with the workload findings presented in Chapter 4. As an observational study, no cause-and-effect relationships could be established between workload and fatigue measures. In addition, the use of subjective measures also introduces the possibility that the supposed effects of perceived workload, such as fatigue, might in fact become a cause of workload. Therefore, a possible bi-directional relationship between perceived workload and fatigue cannot be ruled out (Bowling & Kirkendall, 2012; Hockey et al., 1998; Mejri et al., 2014).

Finally, the workload findings cannot be generalized to other flights that operate with fewer crewmembers, or shorter flights with less or no opportunity for rest and/or a different workload distribution.

Participants in the focus group study (Chapter 5) self-selected into the study. It is possible they did so because fatigue is a major concern for them. However, the present findings corroborate previous research on cabin crew fatigue (Avers, King, et al., 2009; Avers et al., 2011; Castro et al., 2015; Holcomb et al., 2009; Lowden & Åkerstedt, 1998b, 1999; MacDonald et al., 2003; Nesthus et al., 2007; Ono et al., 1991).

It should also be noted that 73% of the participants in the focus group study were male, whereas the proportion of male cabin crew at this airline was about 34% at the time of the study. It is therefore possible that the participants in this study are not entirely representative of their work force. Nevertheless, the richness of the conversation confirmed the usefulness of the focus group approach, which does not aim to provide a representative view. Additional research may involve surveying cabin crew across the whole airline on the extent of their agreement/disagreement with the views raised in the present study (Gander et al., 2018).

6.5 Directions for future research

6.5.1 Workload

Based on the findings presented in Chapters 4 and 5, further research is warranted to determine to what extent workload influences cabin crew fatigue on all types of flight operations. Compared to ULR flights, the effect of workload on fatigue during long-haul flights is expected to be greater as these typically operate with fewer crewmembers and allow less opportunity for in-flight rest, despite similar passenger loads and in-flight services. On short-haul flights, the effect of workload is expected to be greatest, depending on the number of crew on board, in-flight services offered, and number of flight sectors flown per duty period. Importantly, none of these flights should be considered in isolation, as any flow-on effects of workload on subsequent sleep could contribute to cumulative sleep loss and fatigue across a roster worked.

To evaluate whether high perceived workload reduces the recuperative value of in-flight sleep during long haul and ULR flights, future studies monitoring cabin crew fatigue should also consider including a workload rating that immediately precedes cabin crews' in-flight rest.

6.5.2 Cumulative sleep loss, intermittent (partial) recovery, and its effect on subsequent duty

Further research is warranted to examine the effects of cumulative sleep loss, intermittent recovery, and subsequent duty on cabin crew fatigue.

The findings presented in Chapters 3 and 5 highlight that the cumulative effects of sleep restriction and intermittent, potentially incomplete (i.e. partial) recovery are inherent to cabin crew fatigue. Few published field studies have monitored the effects of multiple, successive trips and intermittent recovery on aircrew fatigue (Buck et al., 1989; Gander, Gregory, et al., 1998; Gander, Mulrine, van den Berg, Smith, Wu, et al., 2014; Gander, van den Berg, et al., 2013). Among these studies, only one monitored cabin crews' sleep and fatigue (Buck et al., 1989).

Laboratory-based studies evaluating the dose-dependent cumulative effects of sleep restriction and subsequent recovery have typically involved 5-7 days of sleep restriction followed by 1-13 recovery days (Banks et al., 2010; Belenky et al., 2003; Bougard et al., 2018; Dinges et al., 1997; Rupp et al., 2009; van Leeuwen et al., 2018). One exception is a study by Simpson and colleagues (Simpson et al., 2016), who evaluated the effects of repeated sleep restriction (5 days) and recovery (2 days) over a 3-week period. However, in each of these studies, sleep on recovery days was timed during the biological night and consisted of a single sleep period. In contrast, the recovery sleep of cabin crew is often split after transmeridian and/or night flights and does not always coincide with the biological night. Furthermore, the participants in the laboratory studies were not subject to circadian disruption, as is often the case for cabin crew.

Increasing our understanding of cabin crews' recovery under these conditions may lead to improved scheduling of duty and rest, and better utilization of fatigue mitigation strategies for cabin crew.

6.5.3 The effectiveness of FRMS and perceived organisational support

The findings presented in Chapter 5 highlight the importance of perceived company support in relation to the management of cabin crew fatigue. The success of an FRMS is dependent on the development of a mature safety culture within an organisation, but dissatisfaction with the existing working environment may act as a barrier to this (Gander, Hartley, et al., 2011).

Existing research on perceived organisational support indicates that it has a mediating role in the safety behaviour of employees. The creation of a supportive work environment in which employees perceive that management cares for their well-being, has been shown to influence employees' attitudes and encourage reciprocal behaviour (Baran, Rhoades-Shanock, & Miller, 2012; Hofmann & Morgeson, 1999). This may be in the form of upward safety communication and employees' openness to raise concerns about safety-related issues (Hofmann & Morgeson, 1999) and enhanced safety-related behaviours (Baran et al., 2012), such as prioritizing time for adequate sleep and recovery.

Future studies evaluating the effectiveness of an FRMS within an organisation should therefore consider an evaluation of perceived organisational support (Eisenberger, Huntington, Hutchison, & Sowa, 1986), to determine if, or to what extent, it influences crewmembers' fatigue-related safety communication (including fatigue reporting), and self-management of fatigue.

6.6 Conclusions

This thesis research offers new insights into the current status of, and future needs for FRMS for cabin crew, in particular regarding two key components of the FRMS framework, namely the fatigue risk management processes, and the promotion processes.

Firstly, the present findings demonstrate that collecting fatigue monitoring data, as for flight crew, is also feasible for cabin crew, provided that operational differences between cabin crew and flight crew are considered.

Secondly, using mitigations that mirror those used for flight crew, cabin crew fatigue can be managed effectively on a ULR flight, However, the present findings also highlight the importance of considering the cumulative effects of fatigue across the entire ULR trip, workload, and the impact of the entire roster worked, for improving the management of cabin crew fatigue associated with ULR operations, as well as for cabin crews' fatigue risk management in general.

Thirdly, the present findings highlight the importance of sufficient rest for adequate recovery sleep as well as for facilitating a work-life balance in support of employees' health and well-being.

The findings also highlight the need for company support, in the form of fatigue-related processes and resources, effective communication and management's engagement with cabin crew in general.

In light of the above findings, priority should be given to fatigue management training for cabin crew, which may also enhance perceived company support and assist with achieving a better work-life balance. Finally, viewing fatigue as a compound hazard, the management of the fatigue-related safety risks and health risks may be optimized if FRMS and OHS can be more closely linked or integrated, in support of improving cabin crews' safety and service, and health and well-being.

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APPENDIX A ETHICAL APPROVAL ULR VALIDATION STUDY

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

8 November 2011

Dr Leigh Signal
Sleep/Wake Research Centre
WELLINGTON

Dear Leigh

Re: HEC: Southern A Application – 11/74
Evaluation of sleep and performance on ultra long range (ULR) flights for South African Airways

Thank you for your letter dated 7 November 2011.

On behalf of the Massey University Human Ethics Committee: Southern A I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

A/Prof Hugh Morton, Chair
Massey University Human Ethics Committee: Southern A

cc Prof Philippa Gander, Director
Sleep/Wake Research Centre
WELLINGTON

Massey University Human Ethics Committee
Accredited by the Health Research Council
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MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

24 August 2012

Dr Leigh Signal
Sleep/Wake Research Centre
WELLINGTON

Dear Leigh

Re: HEC: Southern A Application – 11/74
Evaluation of sleep and performance on ultra long range (ULR) flights for South African Airways

Thank you for your letter dated 16 August 2012 outlining the change you wish to make to the above application.

The change, minor edits to the instructions for the completion of the performance tests in flight, has been approved and noted.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee. If over time, more than one request to change the application is received, the Chair may request a new application.

Yours sincerely

Dr Brian Finch, Chair
Massey University Human Ethics Committee: Southern A

cc Prof Philippa Gander, Director
Sleep/Wake Research Centre
WELLINGTON

Massey University Human Ethics Committee
Accredited by the Health Research Council

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MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

22 February 2013

Dr Leigh Signal
Sleep/Wake Research Centre
WELLINGTON

Dear Leigh

Re: HEC: Southern A Application – 11/74
Evaluation of sleep and performance on ultra long range (ULR) flights for South African Airways

Thank you for your letter dated 20 February 2013 outlining the change you wish to make to the above application.

The change, minor amendments to the sleep/duty diary for the Cabin crew, has been approved and noted.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee. If over time, more than one request to change the application is received, the Chair may request a new application.

Yours sincerely

B J Finch.

Dr Brian Finch, Chair
Massey University Human Ethics Committee: Southern A

cc Prof Philippa Gander, Director
Sleep/Wake Research Centre
WELLINGTON

Massey University Human Ethics Committee
Accredited by the Health Research Council

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APPENDIX B PARTICIPANT INFORMATION SHEET ULR VALIDATION STUDY

SLEEP/WAKE research centre
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EVALUATION OF CABIN CREW SLEEP AND PERFORMANCE ON ULTRA LONG RANGE FLIGHTS

INFORMATION SHEET

Researchers Introduction

Researchers from the Sleep/Wake Research Centre, Massey University, New Zealand will be assisting with the collection and analysis of data on Ultra-Long-Range (ULR) flight operations between Johannesburg and New York (JNB-JFK). Members of the research team from the Sleep/Wake Research Centre include Dr. Leigh Signal, Margo van den Berg and Professor Philippa Gander. Their contact details can be found below.

Project Description and Invitation

This study is designed to evaluate the effects of an ULR flight between JNB-JFK on Cabin Crew sleep, and the potential consequences for crewmember fatigue and performance during the trip, and for post-trip recovery. The study will also assist SAA to develop its own in-house capacity to collect and analyse fatigue measures, namely: actigraphy and sleep/duty diaries; subjective fatigue and sleepiness ratings; and Palm Pilot-based PVT performance as part of its Fatigue Risk Management System.

The aims of the project are to:

- Objectively measure the amount and quality of sleep that Cabin Crew are able to obtain prior to, during and after ULR flights
- Document the subjective sleepiness, fatigue and workload of Cabin Crew during ULR flights.
- Document alertness (using a 5-minute vigilance task) of Cabin Crew during ULR flights
- Compare sleep, subjective ratings and alertness on JNB-JFK flights against previous ULR routes where similar data has been collected.

Participant Identification and Recruitment

All Cabin Crew who fly the JNB-JFK-JNB ULR trips are eligible to participate. The aim is to recruit 50 Cabin Crew in total for data collection.

Project Procedures

When the monthly flight schedules are made available, if you are scheduled on a JNB-JFK study trip, you will receive a phone call explaining the study in detail and have a chance to ask questions. If you decide to participate, you will need to complete the written consent form (included in this study pack).

All information that you provide will be confidential and identified only by a study ID number.

If you decide to participate, you will be asked to do the following;

Before the study trip

- Approximately 5-7 days before the outbound leg, you will receive a study pack. This includes an Actigraph and sleep/duty diary (see photo) and a PDA device. The Actigraph should be worn continuously and the diary completed for:
    - 3 days before the outbound leg;
    - throughout the outbound leg, layover and inbound leg;
    - for 5 days after your return to JNB.

  The Actigraph is waterproof down to 1 meter for 30 minutes. This means you should take it off if you will be in water for longer than this.

  The Actigraph is the same size as a watch and is worn on your non-dominant wrist. It measures activity continuously, and this information can be analysed subsequently to estimate when, how long, and how well you have slept. The sleep/duty diary provides additional information on when you try to sleep and how you rate the quality of each sleep episode. It also has spaces for you to rate your levels of fatigue and sleepiness.

- The sleep/duty diary includes a short questionnaire to collect general demographic and sleep information (age, Cabin Crew position, experience, normal sleep habits at home, and normal sleep habits in-flight). Please complete this before you depart on your outbound leg.
- The study pack also includes a Palm Pilot Personal Data Assistant (PDA) which contains a 5-minute reaction time test used to assess in-flight alertness. You will receive a briefing on how to activate the device and complete the test.
- The study pack also includes a CD with powerpoint slides which contain detailed information about the use of the sleep/duty diary, the actigraph and the reaction time test on the PDA.
- Prior to the start of the data collection, a time will be arranged when a member of the research team will meet with you and explain the study and the use of the equipment in detail.
- Approximately 3-4 days prior to the outbound leg you will receive a phone call from a member of the research team to remind you to commence the data collection and answer any further questions you may have.

The day of each flight

- Before the crew briefing, you need to complete a section of your sleep/duty diary that contains information on the current flight, evaluate your sleepiness and fatigue, and complete the reaction time test on the PDA. It is very important that, if possible, the test is completed in an area free of distractions.
- You are asked to rate your sleepiness and fatigue pre and post flight, at top of climb and top of descent, and pre and post each in-flight sleep, and to record all in flight sleep obtained (including the location and quality of this sleep)

- You are also asked to complete the reaction time test on the PDA within 90 minutes after take-off and within 90 minutes prior landing. It is very important that, if possible, the test is completed in an area free of distractions.
- After landing, you are asked to complete another section of your sleep/duty diary that contains information on the arrival time of the current flight and your workload.

<u>During the layover</u>

- You are asked to continue to wear the Actigraph and complete the sleep/duty diary during the layover.

<u>After your study trip</u>

- Please continue to complete the sleep/duty diary and wear the Actigraph for 5 days after the return flight.
- Once data collection is complete, you can then return your actigraph, sleep/duty diary and PDA directly to Wynand Serfontein or the designated research team member in Flight Operations, Room 304, CRM and Fatigue Management Office at South African Airways.

Data Management.

- Data will be analyzed by researchers at the Sleep/Wake Research Centre, Massey University, New Zealand.
- Completion of this study will contribute towards Margo van den Berg's Doctoral degree, under supervision of Dr. Leigh Signal and Professor Philippa Gander.
- The findings of the study will be published in a final report. You will receive a summary of the findings of the study and have access to a copy of the final report.
- None of the data collected will have your name recorded on it. Instead it will have a study ID number. Researchers at the Sleep/Wake Research Centre will not have access to your name or contact information and during data collection South African Airways personnel will not be able to access your data. No material that could personally identify you will be used in any reports on the study.
- At the end of the project databases will be made available to South African Airways for the purposes of developing their Fatigue Risk Management System. All data in the databases will be identified by code numbers only, all dates will be removed, and there will be no way of personally identifying your data.
- Additionally, de-identified data from all Cabin Crew in this study may subsequently be used for additional analyses, including testing and improving mathematical models of crew fatigue. This will involve combining de-identified data with data from other airlines in a combined dataset, which may be accessed by other groups taking part in these analyses.
- All data will be stored in secure facilities at the Sleep/Wake Research Centre, Massey University. The data will be kept for a minimum of 10 years after the study has been completed. It will then be archived.

Risks, Discomforts, and Inconveniences

Risk. The possible risks from this data collection effort may include minor discomfort due to the wristband on the Actigraph from a local allergic reaction to its metallic surfaces. If redness and itching occurs, please notify the research team and corrective measures can be taken, such as applying tape to the underside of the Actigraph where skin contact is apparent.

Discomforts. Wearing the wrist activity monitor during sleep may be considered uncomfortable if you are not accustomed to wearing a wristwatch during that time.

Inconveniences. Wearing the Actigraph during this study may be considered an inconvenience. With repeated PDA testing, boredom may occur, though optimal effort is required throughout the assessment period for meaningful data. Test times will require 5 min each time and diary entries will require an estimated 1-2 min each time.

Benefits

You will be contributing to an improved understanding of the fatigue associated with ULR flying, and the effectiveness of scheduling duty and rest opportunities designed to reduce exposure to fatigue, maintain alertness and safety of flight operations.

Once your participation in the study is complete you may contact researchers at the Sleep/Wake Research Centre to receive feedback on your individual data. To identify your data you will need to provide the researchers with your identification code.

Compensation and Injury: Medical care and compensation is available through your South African Airways employee procedure if an injury occurs through your participation in this data collection effort.

Participant's Rights

You are under no obligation to accept this invitation to participate in this research. If you decide to participate, you have the right to:

- Decline to answer any particular question;
- Withdraw from the study at any time;
- Have any of your personal data handed back to you and removed from all datasets at any time;
- Ask any questions about the study at any time during participation;
- Provide information on the understanding that none of your data will have your name on it (an identification number is used instead), and you will not be identified in any reports on the study;
- Be given access to a summary of the study findings when it is concluded.

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 11/74. If you have any concerns about the conduct of this research, please contact Associate Professor Hugh Morton, Chair, Massey University Human Ethics Committee: Southern A, telephone +64 6 350 5799 x 4265, email humanethicsoutha@massey.ac.nz.

Project Contacts

If you have any further questions about this study please do not hesitate to contact us at the below phone number, or by e-mail.

Dr. Leigh Signal	Margo van den Berg	Prof. Philippa Gander
t.l.signal@massey.ac.nz	m.j.vandenberg@massey.ac.nz	p.h.gander@massey.ac.nz
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APPENDIX C CONSENT FORM ULR VALIDATION STUDY

SLEEP/WAKE *research centre*
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EVALUATION OF CABIN CREW SLEEP AND PERFORMANCE ON ULTRA LONG RANGE FLIGHTS

PARTICIPANT CONSENT FORM

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I wish / do not wish to have my de-identified data placed in a combined dataset for sharing with other airlines.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... **Date:** ....

Full Name - printed ....

Consent Form – South African Airways Cabin Crew study – September 2011 Page 1 of 1

APPENDIX D SAMPLE SIZE ESTIMATION ULR VALIDATION STUDY

All power calculations were performed by Associate Professor Leigh Signal.

The sample size estimation for this study was based on power calculations conducted for South African Airways' flight crew study (Signal et al., 2014), as there was no cabin crew data available for this purpose. The flight crew power calculations were based on comparisons to be made between the primary crew (who perform take-off and landing) and secondary (relief) crew. Similarly, the cabin crew operate as A and B crew. Data was used from Singapore ULR operations between Singapore and Los Angeles (Signal et al., 2004) and Delta Air Lines ULR operations between Atlanta and Johannesburg (Gander, van den Berg, et al., 2011).

Using Lenth's *Java Applets for Power and Sample Size* Computer software (Lenth, 2006-9), two-tailed independent t-tests were performed at 80% statistical power and alpha level of 0.05.

D.1 In-flight sleep

Sample size required to detect a 0.75-hour difference in sleep duration during a ULR flight (in-flight sleep):

- Based on Delta Air Lines SD=43-73; Singapore Airlines SD 58-92; Mean SD =63, n=25;
- Mean sleep durations were between 2.4 and 4.1 hours, thus a decrease in sleep of 0.75 hour represents approximately a 31% change;

- Estimated required sample size: 43 A-crew and 43 B-crew.

If 25 A-crew and 25 B-crew were studied, a change in sleep of 0.85 of an hour (35% change) would be able to be detected.

D.2 Samn-Perelli Crew Status Check

Sample size required to detect a 1-point difference on the Samn-Perelli Crew Status Check at top of TOD:

- Based on: Delta Air Lines SD=1.1-1.2; Singapore Airlines SD 1.0-1.2; Mean SD = 1.2, n=28;
- Median fatigue ratings close to TOD during a ULR flight were between 3 and 4, thus an increase in fatigue of 1 of the Samn-Perelli scale represents approximately a 33% change;
- Estimated required sample size: 21 A-crew and 21 B-crew.

D.3 Karolinska Sleepiness Scale

Sample size required to detect a 1-point difference on the Karolinska Sleepiness Scale at TOD:

- Based on: Delta Air Lines SD=1.1-1.9; Singapore Airlines SD 1.1-2.22; Mean SD = 1.5, n=28;
- Median sleepiness ratings close to TOD during a ULR flight were between 3.5 and 6, thus an increase in sleepiness of 1 of the Karolinska Sleepiness Scale represents approximately a 29% change;

- Estimated required sample size: 51 A-crew and 51 B-crew.

D.4 Psychomotor Vigilance Task (PVT) Response Speed

Sample size required to detect a change in performance of 0.5 responses per second (response speed) at TOD:

- Based on: Delta Air Lines SD=0.47-0.54; Singapore Airlines SD 0.58-0.83; Mean SD = 0.61, n=24;
- Mean response speed at TOD during a ULR flight was between 3.96-4.22 responses per second, thus a decrease in performance of 0.5 responses per second represents a 12.5% reduction in response speed;
- Estimated required sample size: 25 A-crew and 25 B-crew.

D.5 Sample size required

Considering that a) sleep was the most important measure in this study and b) it was financially not feasible to have 102 crewmembers participate (N required to detect a 1-point chance at TOD on the Karolinska Sleepiness scale), it was determined that the minimum required sample size is **50**.

APPENDIX E SLEEP/DUTY DIARY

EVALUATION OF CABIN CREW SLEEP AND PERFORMANCE ON ULTRA LONG RANGE FLIGHTS

CABIN CREW SLEEP/DUTY DIARY

Please call Carol - 0820971909
Ayanda - 079 974 8826
Beverly - 072 5035437

if you have any questions at any time

ID | | | | |

1

WHEN TO DO WHAT

HOME PRE-TRIP	Complete Pre-Study Questionnaire. Record trips over past week in Look Back Report. Fill out the sleep/duty diary for 3 days prior to the outbound leg of the study flight .
BEFORE EACH FLIGHT	
Before take-off	Answer questions & rate your fatigue and sleepiness. Complete a performance test (PalmPVT).
At top of climb	Rate your fatigue and sleepiness. Complete a performance test (PalmPVT) after take-off when the seat belt sign goes off, within 90 minutes after take-off.
When starting each break opportunity	Fill out your sleep/duty diary and rate your fatigue and sleepiness.
When ending each break opportunity:	Fill out your sleep/duty diary and rate your fatigue and sleepiness.
At top of descent	Rate your fatigue and sleepiness. Complete a performance test (PalmPVT) at the end of the last meal service, within 90 minutes before landing.
After landing, prior to disembarking	Answer questions and rate your fatigue, sleepiness and workload (the workload index may be completed within 15 minutes after disembarking the aircraft).
DURING LAYOVER	Fill out your sleep/duty diary.
POST-TRIP	Fill out your sleep/duty diary for 5 days following the inbound leg of the study flight (even if you are on a flight within these 5 days).

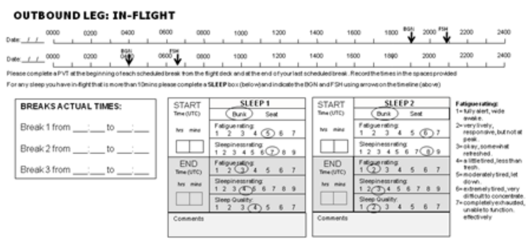
2

INFORMATION ABOUT WEARING THE ACTIGRAPH AND COMPLETING THE SLEEP/DUTY DIARY

The small watch sized object you will be wearing on your wrist is an actigraph. It contains an accelerometer and memory chip and records movement. The data from the actigraph is analysed along with the information from the sleep/duty diary to determine sleep length and sleep quality.

Information about wearing the actigraph:

1. Only wear the actigraph on your non-dominant wrist (the hand you don't write with) and place it so that the clock face is the right way up.
2. The actigraph should be attached reasonably firmly so that it does not move about on your wrist. If the black border on the clock face is flashing, the actigraph is not fastened properly (too loose or too tight). Please adjust accordingly.
3. The actigraph is waterproof down to 1 meter for 30 minutes. This means you should take it off if you will be in water for longer than this.
4. If you take the actigraph off for any reason then please note this in your sleep/duty diary and note the time when you put the actigraph back on.
5. **We cannot tell what you are doing from the actigraph data. We can only tell whether you are moving or not.**
6. The button on the <u>left side</u> is a marker button. If you push this for **3+ seconds**, a small mark will appear on the data output. It does not stop or start the actigraph. The actigraph will keep going the entire time you are wearing it. Data collection is indicated by the circling black border on the clock face.
7. We would like you to push the marker button when you start trying to sleep and again when you stop trying to sleep. Please do this whenever you intend to sleep for **10 minutes or longer**.
8. The time displayed on the clock face is in UTC. Pressing the backlight button (located on the right) for 3 seconds will reveal the date (DD-MM) in UTC.


OUTBOUND LEG: IN-FLIGHT

Date: _/_/_ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 BGN 2000 FSH 2200 2400

Date: _/_/_ 0000 0200 BGN 0400 0600 FSH 0800 1000 1200 1400 1600 1800 2000 2200 2400

Please complete a PVT at the beginning of each scheduled break from the flight deck and at the end of your last scheduled break. Record the times in the spaces provided

For any sleep you have in-flight that is more than 10mins please complete a **SLEEP** box (below) and indicate the BGN and FSH using arrows on the timeline (above)

BREAKS ACTUAL TIMES:
Break 1 from ___:___ to ___:___
Break 2 from ___:___ to ___:___
Break 3 from ___:___ to ___:___

START Time (UTC) hrs mins	SLEEP 1	START Time (UTC) hrs mins	SLEEP 2
	Bunk Seat		Bunk Seat
	Fatigue rating: 1 2 3 4 5 6 7		Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9		Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7	END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9		Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7		Sleep Quality: 1 2 3 4 5 6 7
Comments		Comments	

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Information about filling out the sleep/duty diary

<u>When NOT ON the aircraft</u>

1. We are interested in **any** sleep that is 10 minutes or longer. It does not matter whether this is during the day or during the night. Each page of the sleep/duty diary allows for up to four sleep periods per 24-hours.
2. The information that is important to us are the times that you **begin trying to sleep** and when you **finish trying to sleep** after any sleep that is **10 minutes or longer.**
3. When you are about to **begin trying to sleep:**
   a. Beginning (BGN) is the time when you begin trying to sleep. Some people may get into bed and read etc, but we do not need to know this, we only need to know when you begin trying to go to sleep.
   b. Write the time in hours and minutes in the corresponding Sleep box and mark it in the timeline with an arrow and write 'BGN' plus the time above or under it.
   c. Rate your levels of **Fatigue** and **Sleepiness** by circling a number in the corresponding Sleep box.
4. When you have **finished trying to sleep:**
   a. Finished (FSH) is when you wake up and are no longer trying to sleep. At this time you may either get out bed or begin to read etc, but you are no longer trying to sleep.
   b. Write the time in hours and minutes in the corresponding Sleep box and mark it in the timeline with an arrow and write 'FSH' plus the time above or under it.
   c. Rate your levels of **Fatigue** and **Sleepiness** by circling a number in the corresponding Sleep box.
   d. Rate also the **quality** of your sleep by circling a number.
5. Please record all times in UTC. A UTC conversion chart is included at the back of this diary and the time displayed on the actigraph's clock face is in UTC.
6. **Beginning** and **Finish** are the times we would like you to push the marker button on the actigraph.
7. If you wake up during your sleep to get a drink, go to the toilet etc, you do not need to write anything in the sleep/duty diary. If you get up for **more than 10 minutes** then please treat any later sleep as a new sleep period.

<u>When ON the aircraft</u>

1. Sleep in flight should be recorded using the guidelines above.
2. In addition, the location of the sleep should be noted.
3. In addition to recording details about your sleep, the sleep/duty diary contains pages for recording information prior to the flight, at top of climb, top of descent and post flight. Please complete the sections as required. However, do not fill in the questionnaire at TOC and TOD if you feel that this may interfere with your work and compromise safety.

3

PalmPVT TEST INSTRUCTIONS

The test you are being asked to perform measures your ability to continuously monitor and respond to a stimulus on a Palm PDA

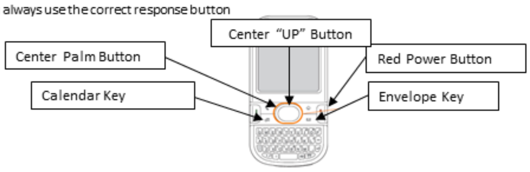
Please perform this test in a quiet place. It is important that there are no distractions, good lighting and that you can sit comfortably. Hold the device with both hands and have your thumb or finger resting on the response button.

Components of the test

1. Activate the screen of the device by tapping the red power button (middle, right-hand side of phone) and pressing the center 'palm' button to unlock the keypad.
2. To open the PalmPVT software, select the PalmPVT icon on the 'Home' screen.
   If the icon is not visible, press the side button located on the left side of the PDA (below the volume button). PalmPVT
3. Once the PalmPVT software opens, your ID number will appear in the small box at the bottom of the screen.
   The screen reads "SELECT BUTTON". If you are left handed press the Calendar Key. If you are right-handed press the Envelope Key. This step is customizing the trigger button of the test to your desired hand. You will only be asked to do this once, the first time you do the test, so make sure you set the correct button.
4. Once you have completed step 3, the first screen you will see each time will be the start test screen.
   When you are ready to start the test, press the "UP" button (The center UP button is the top part of the silver ring surrounding the center 'palm' button).
5. **TRY TO DO YOUR BEST AND GET THE LOWEST NUMBER YOU POSSIBLY CAN**
6. The test will take five minutes to complete. When the test is complete you will be taken back to the 'Home' screen.
7. Remember to deactivate the screen after each test by briefly pressing the power button on the right-hand side once. **This reduces battery consumption. Please do not hold the power button down (therefore only tap once), as this will turn on the 'Phone' feature on the device. Since no SIM card is inserted, a warning message will appear.**

Possible mistakes

If you press the button too early (before the target appears) you will see the message "FALSE START!".
If you touch the screen, an error message will appear "please don't touch the screen!"
If you forget to release the button, after a short time the test will remind you "please don't hold down this button!".
If you press the wrong button one either an error message will appear "please don't use this button!" OR the response will not register, it is important that you always use the correct response button



4

Pre-Study Questionnaire

Professional Experience

1. How long have you been working as Cabin Crew? (total time in all airlines you have worked for) _______ / _______ yrs. mths.
2. How long have you been flying long-range? (*flights > 5 hours*) _______ / _______ yrs. mths.
3. How long have you been flying ultra-long-range ? (*flights > 16 hours*) _______ / _______ yrs. mths.
4. Which position do you normally fly? ☐ Cabin Crew ☐ Purser ☐ Senior Purser
5. On average, how many hours per month do you work? _______ hrs.
6. How many duty hours do you expect to do in the month that includes the study flights? _______ hrs.
7. How long does it take you to travel to work? _______ hrs/mins

Demographics

8. What is your age? _______________
9. Gender: ☐ Male ☐ Female

ID ☐☐☐☐

Sleep at Home on your days off

10. On average, how many nights of sleep do you obtain at home between scheduled trips? _______ nights
11. On your days off, what time do you usually go to sleep? *(please use 24-hour clock and local time)* ☐☐ hrs. ☐☐ mins.
12. On your days off, what time do you usually get up? *(please use 24-hour clock and local time)* ☐☐ hrs. ☐☐ mins.
13. On your days off, how long after going to bed do you usually take to fall asleep? ☐☐ hrs ☐☐ mins.
14. When sleeping at home, do you have problems getting to sleep at night? ☐ never ☐ seldom (1-4 times /yr) ☐ sometimes (1-3 times /mth) ☐ often (1-4 times /wk) ☐ always (daily)
15. If you do experience problems falling asleep what is it that usually keeps you awake? _______________
16. When sleeping at home, how many times on average do you wake during the night? _______ times.
17. If you usually wake during the night, what is it that usually causes you to awaken? _______________

Please continue the questions on the following page

Sleep at Home on your days off (continued)

18. If you wake during the night, on average, how difficult is it to go back to sleep? ☐ very easy ☐ reasonably easy ☐ ☐ difficult ☐ very difficult
19. When sleeping at home, what is the total amount of sleep you get at night? ☐☐ hrs. ☐☐ mins.
20. How often do you take a daytime nap at home? ☐ never ☐ seldom (1-4 times /yr) ☐ sometimes (1-3 times /mth) ☐ often (1-4 times /wk) ☐ always (daily)
21. Do you take anything to help you sleep? ☐ never ☐ seldom (1-4 times /yr) ☐ sometimes (1-3 times /mth) ☐ often (1-4 times /wk) ☐ always (daily)
    a. If yes, please specify: _______________
22. Overall what kind of sleeper would you consider yourself to be? ☐ Very Poor ☐ Poor ☐ Average ☐ Good ☐ Very good
23. Do you have a sleep problem? Yes / No *(please circle)*
    a. If yes; what is your sleep problem? _______________
    b. Has it been diagnosed by a physician? Yes / No *(please circle)*
    c. Has it ever prevented you from flying a scheduled trip? Yes / No *(please circle)*

ID ☐☐☐☐

Sleep In-flight

Please answer these questions based on your past experience sleeping in the aircraft

24. Approximately how many times during the past 12 months have you slept on an aircraft bunk or seat? a) Bunk: _______ times b) Seat: _______ times
25. How long has it usually taken you to fall asleep in the: a) Bunk: ☐☐ hrs. ☐☐ mins. b) Seat: ☐☐ hrs. ☐☐ mins.
26. What is the typical amount of sleep you get in the: a) Bunk: ☐☐ hrs. ☐☐ mins. b) Seat: ☐☐ hrs. ☐☐ mins.
27. How often do you use the bunk or seat only for rest and not sleep? a) Bunk: _______ times b) Seat: _______ times
28. How much of your rest time do you normally spend sleeping in the: a) Bunk: _______ % b) Seat: _______ %
29. In general, how would you assess the quality of your sleep in a bunk or seat?
    bunk ☐ ☐ ☐ ☐ ☐
    seat ☐ ☐ ☐ ☐ ☐
    Very Poor / Poor / Average / Good / Very good
30. How does bunk or seat sleep affect your overall alertness?
    bunk ☐ ☐ ☐ ☐ ☐
    seat ☐ ☐ ☐ ☐ ☐
    very decreased alertness / decreased alertness / no change / improved alertness / very improved alertness

Please continue the questions on the following page

31. How does bunk and seat sleep affect your performance?

	very decreased performance	decreased performance	no change	improved performance	very improved performance
bunk	☐	☐	☐	☐	☐
seat	☐	☐	☐	☐	☐

Alertness, Fatigue and Performance

32. If/when you experience fatigue during a work period, during which phase of flight is your performance usually most affected?

- ☐ N/A (fatigue doesn't affect my performance)
- ☐ Taxi
- ☐ Takeoff
- ☐ En route
- ☐ Descent
- ☐ Approach/landing

33. Which of the following aspects of your work are most affected if/when you experience fatigue during a work period?

- ☐ N/A
- ☐ Pre-flight safety briefing
- ☐ Provision of snacks/drinks
- ☐ Provision of meals
- ☐ Response to passenger needs (incl. service and safety related items)
- ☐ Cabin safety (e.g. arming/disarming doors, verifying carry-on items stowed or seatbelts fastened)
- ☐ Cabin security (e.g. passenger risk assessment)
- ☐ Other, please specify: ________________________________

Comments:

ID ☐☐☐☐

Please continue the questions on the following page

LOOK BACK REPORT

Please record any **duty periods** in the week prior to beginning this study

	DAY	DD	MM	YY	ON-DUTY/OFF-DUTY	FLIGHT FROM	FLIGHT TO	FLIGHT #	OVERNIGHT CITY
PREVIOUS WEEK'S ACTIVITIES									
STUDY PERIOD STARTS ↓					HOME				
					HOME				
					HOME				

I.D. ☐☐☐☐

HOME PRE-TRIP: DAY 1

Date ____/____/____ (UTC)
dd mm yy

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

City: ___________

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)
START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7
START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7
END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D. [ ][ ][ ][ ]

9

HOME PRE-TRIP: DAY 2

Date ____/____/____ (UTC)
dd mm yy

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

City: ___________

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)
START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7
START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7
END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D. [ ][ ][ ][ ]

10

HOME PRE-TRIP: DAY 3

Date ____/____/____ (UTC)
dd mm yy

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

City: ____________

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)
START – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D. [ ][ ][ ][ ]

11

OUTBOUND LEG: PRE-FLIGHT and TOC

DATE: _____/_____/_____ (UTC)
dd mm yy

1. What was your scheduled sign-on time? [ ][ ] hrs min
   (Please use UTC and 24-hr clock)
2. What was your actual sign-on time? [ ][ ] hrs min
   (Please use UTC and 24-hr clock)
3. Time off blocks: [ ][ ] hrs min
   (Please use UTC and 24-hr clock)
4. What is your crew position? ☐ Galley ☐ Aisle ☐ Other:_________
5. In which cabin are you working: ☐ Premium ☐ Economy
6. How many times have you flown this route before? _____ times
7. What are your planned break patterns for today's flight?
   (Please use UTC and 24-hr clock)
   Start: [ ][ ] hrs min End: [ ][ ] hrs min
   Start: [ ][ ] hrs min End: [ ][ ] hrs min
   Start: [ ][ ] hrs min End: [ ][ ] hrs min

Pre-flight in Briefing Room:
Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9
Time PalmPVT done: ___:___

Time at TOC: [ ][ ] hrs min
Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9
Time PalmPVT done: ___:___
(Within 90 mins after take-off, and after seat belt sign is off)

I have the: 1st 2nd 3rd 4th rest break. (please circle)

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function. effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep

8. How do you typically manage fatigue on this flight?________________________________

Additional Comments________________________________

I.D. [ ][ ][ ][ ]

12

OUTBOUND LEG: IN-FLIGHT

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

For any sleep you have in-flight that is more than 10mins please complete a **SLEEP** box (below) and indicate the BGN and FSH using arrows on the timeline (above)

BREAKS ACTUAL TIMES:

Break 1 from ___:___ to ___:___

Break 2 from ___:___ to ___:___

Break 3 from ___:___ to ___:___

START Time (UTC) hrs mins	SLEEP 1 Bunk Seat
	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

START Time (UTC) hrs mins	SLEEP 2 Bunk Seat
	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

START Time (UTC) hrs mins	SLEEP 3 Bunk Seat
	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

START Time (UTC) hrs mins	SLEEP 4 Bunk Seat
	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

START Time (UTC) hrs mins	SLEEP 5 Bunk Seat
	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC) hrs mins	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function. effectively

Sleep Quality:
1= extremely good
7= extremely poor

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep

I.D.

13

OUTBOUND LEG: TOD and POST-FLIGHT

DATE: ______/______/______(UTC)
dd mm yy

Time at TOD: hrs min

Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9
Time PalmPVT done: **(At end of last meal service, within 90 mins before landing)** ___:___

After Landing:
(Before disembarking aircraft)

Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function. effectively

1. Time on blocks: hrs min

2. What time did you sign off duty? hrs min

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep

Comments____

____

____

I.D.

14

OUTBOUND: POST-FLIGHT

DATE: ______ / ______/ ______ (UTC)
dd mm yy

NASA Task Load Index:

Place an 'X' in the position that best describes your experience. Note that 'your success in accomplishing tasks' is rated from 'good' to 'poor'.

How mentally demanding was the flight?	Low	| | | | | | | | | | | | | | | | | | | | |	High
How physically demanding was the flight?	Low	| | | | | | | | | | | | | | | | | | | | |	High
How hurried or rushed was the pace of the flight?	Low	| | | | | | | | | | | | | | | | | | | | |	High
How successful were you in accomplishing what you were asked to do?	Good	| | | | | | | | | | | | | | | | | | | | |	Poor
How hard did you have to work to accomplish your level of performance?	Low	| | | | | | | | | | | | | | | | | | | | |	High
How insecure, discouraged, irritated, stressed and annoyed were you?	Low	| | | | | | | | | | | | | | | | | | | | |	High

Post-Duty Service Questionnaire

How many passengers were on the flight? _______passengers.

Did your flight get delayed?	☐ Yes	☐ No
Did you experience turbulence?	☐ Yes	☐ No
Did you have unruly passengers?	☐ Yes	☐ No
Did you have a medical incident?	☐ Yes	☐ No
Did you have an emergency incident?	☐ Yes	☐ No
Did you have any major service disruptions?	☐ Yes	☐ No

How many times did you assist with baggage? ________times.

Comments:

I.D. ☐☐☐☐

15

LAYOVER: HOURS 1-24

Date ____ /____ /____ (UTC)
dd mm yy

For any sleep you have that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline.

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:_____:_____ (UTC) END: _____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END: _____:_____ (UTC)	START:_____:_____ (UTC) END: _____:_____ (UTC)
START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7	START – Fatigue rating: 1 2 3 4 5 6 7
START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9	START – Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7	END – Fatigue rating: 1 2 3 4 5 6 7
END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9	END – Sleepiness rating: 1 2 3 4 5 6 7 8 9
END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7	END – Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D. ☐☐☐☐

16

LAYOVER: HOURS 25-48 Date: ____ /____ /____ (UTC)
dd mm yy

For any sleep you have that is <u>more than 10mins</u> please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline.

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)
START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9
END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7

<u>Fatigue</u> rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

<u>Sleepiness</u> rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

<u>Sleep Quality</u>:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D. [ ][ ][ ][ ]

17

LAYOVER: HOURS 48+ Date: ____ /____ /____ (UTC)
Use if delayed
dd mm yy

For any sleep you have that is <u>more than 10mins</u> please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline.

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)	START:_____:_____ (UTC) END:_____:_____ (UTC)
START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9
END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END — Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7

<u>Fatigue</u> rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

<u>Sleepiness</u> rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

<u>Sleep Quality</u>:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D. [ ][ ][ ][ ]

18

INBOUND LEG: PRE-FLIGHT and TOC

DATE: ______/ ______/ ______ (UTC)
dd mm yy

1. What was your scheduled sign-on time? [ ][ ] hrs min
   (Please use UTC and 24-hr clock)
2. What was your actual sign-on time? [ ][ ] hrs min
   (Please use UTC and 24-hr clock)
3. Time off blocks: [ ][ ] hrs min
   (Please use UTC and 24-hr clock)
4. What is your crew position? [ ] Galley [ ] Aisle [ ] Other:_________
5. In which cabin are you working: [ ] Premium [ ] Economy
6. How many times have you flown this route before? _____ times
7. What are your planned break patterns for today's flight? Start: [ ][ ] hrs min End: [ ][ ] hrs min
   (Please use UTC and 24-hr clock) Start: [ ][ ] hrs min End: [ ][ ] hrs min
   Start: [ ][ ] hrs min End: [ ][ ] hrs min

Pre-flight, in Briefing Room:

Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9
Time PalmPVT done: ___:___

Time at TOC: [ ][ ] hrs min

Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9
Time PalmPVT done: ___:___ **(Within 90 mins after take-off, and after seat belt sign is off)**

I have the: 1st 2nd 3rd 4th rest break. (please circle)

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function. effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep

8. How do you typically manage fatigue on this flight?____
____

Additional Comments____
____

I.D. [ ][ ][ ][ ]

19

INBOUND LEG: IN-FLIGHT

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

For any sleep you have in-flight that is more than 10mins please complete a **SLEEP** box (below) and indicate the BGN and FSH using arrows on the timeline (above)

BREAKS ACTUAL TIMES:

Break 1 from ___:___ to ___:___

Break 2 from ___:___ to ___:___

Break 3 from ___:___ to ___:___

	SLEEP 1
START Time (UTC)	Bunk Seat
hrs mins [ ][ ]	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC)	Fatigue rating: 1 2 3 4 5 6 7
hrs mins [ ][ ]	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

	SLEEP 2
START Time (UTC)	Bunk Seat
hrs mins [ ][ ]	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC)	Fatigue rating: 1 2 3 4 5 6 7
hrs mins [ ][ ]	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

	SLEEP 3`
START Time (UTC)	Bunk Seat
hrs mins [ ][ ]	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC)	Fatigue rating: 1 2 3 4 5 6 7
hrs mins [ ][ ]	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

	SLEEP 4
START Time (UTC)	Bunk Seat
hrs mins [ ][ ]	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC)	Fatigue rating: 1 2 3 4 5 6 7
hrs mins [ ][ ]	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

	SLEEP 5
START Time (UTC)	Bunk Seat
hrs mins [ ][ ]	Fatigue rating: 1 2 3 4 5 6 7
	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Time (UTC)	Fatigue rating: 1 2 3 4 5 6 7
hrs mins [ ][ ]	Sleepiness rating: 1 2 3 4 5 6 7 8 9
	Sleep Quality: 1 2 3 4 5 6 7
Comments	

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function. effectively

Sleep Quality:
1= extremely good
7= extremely poor

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep

I.D. [ ][ ][ ][ ]

20

INBOUND LEG: TOD and POST-FLIGHT

DATE: ______/ ______/ ______ (UTC)
dd mm yy

Time at TOD: [ ][ ] hrs min

Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9
Time PalmPVT done: (At end of last meal service, within 90 mins before landing) ____:____

After Landing:
(Before disembarking aircraft)

Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function. effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep

1. Time on blocks: [ ][ ] hrs min
2. What time did you sign off duty? [ ][ ] hrs min

Comments____

____

____

I.D. [ ][ ][ ][ ]

21

INBOUND LEG: POST-FLIGHT

DATE: ______/ ______/ ______(UTC)
dd mm yy

NASA Task Load Index:
Place an 'X' in the position that best describes your experience. Note that 'your success in accomplishing tasks' is rated from 'good' to 'poor'.

How mentally demanding was the flight?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How physically demanding was the flight?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How hurried or rushed was the pace of the flight?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How successful were you in accomplishing what you were asked to do?	Good	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	Poor
How hard did you have to work to accomplish your level of performance?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How insecure, discouraged, irritated, stressed and annoyed were you?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High

Post-Duty Service Questionnaire

How many passengers were on the flight?	________passengers.	
Did your flight get delayed?	☐ Yes	☐ No
Did you experience turbulence?	☐ Yes	☐ No
Did you have unruly passengers?	☐ Yes	☐ No
Did you have a medical incident?	☐ Yes	☐ No
Did you have an emergency incident?	☐ Yes	☐ No
Did you have any major service disruptions?	☐ Yes	☐ No
How many times did you assist with baggage?	________times.	

Comments:

I.D. [ ][ ][ ][ ]

22

POST-TRIP: DAY 1

Date ____/____/____ (UTC)
dd mm yy

City: ___________

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)
START Fatigue rating: 1 2 3 4 5 6 7	START Fatigue rating: 1 2 3 4 5 6 7	START Fatigue rating: 1 2 3 4 5 6 7	START Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Fatigue rating: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9
Sleep Quality: 1 2 3 4 5 6 7	Sleep Quality: 1 2 3 4 5 6 7	Sleep Quality: 1 2 3 4 5 6 7	Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D.

23

POST-TRIP: DAY 2

Date ____/____/____ (UTC)
dd mm yy

City: ___________

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date: / / 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)
START Fatigue rating: 1 2 3 4 5 6 7	START Fatigue rating: 1 2 3 4 5 6 7	START Fatigue rating: 1 2 3 4 5 6 7	START Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Fatigue rating: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7
Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9	Sleepiness rating: 1 2 3 4 5 6 7 8 9
Sleep Quality: 1 2 3 4 5 6 7	Sleep Quality: 1 2 3 4 5 6 7	Sleep Quality: 1 2 3 4 5 6 7	Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D.

24

POST-TRIP: DAY 3

Date ____/____/____ (UTC)
dd mm yy

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

City: ___________

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

	SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)
START	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9
END	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D.

25

POST-TRIP: DAY 4

Date ____/____/____ (UTC)
dd mm yy

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

City: ___________

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date:__/__/__ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

	SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)
START	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9
END	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

I.D.

26

POST-TRIP: DAY 5

Date ____/____/____ (UTC)
dd mm yy

For any sleep that is more than 10mins please complete a **SLEEP** box and indicate the beginning (BGN) and finish (FSH) of each sleep using arrows on the timeline

City: ___________

Date: _/_/_ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Date: _/_/_ 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

SLEEP 1	SLEEP 2	SLEEP 3	SLEEP 4
START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END:____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)	START:____:____ (UTC) END: ____:____ (UTC)
START Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9	START Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9
END Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7	END Fatigue rating: 1 2 3 4 5 6 7 Sleepiness rating: 1 2 3 4 5 6 7 8 9 Sleep Quality: 1 2 3 4 5 6 7

Fatigue rating:
1= fully alert, wide awake.
2= very lively, responsive, but not at peak.
3= okay, somewhat refreshed.
4= a little tired, less than fresh.
5= moderately tired, let down.
6= extremely tired, very difficult to concentrate.
7= completely exhausted, unable to function effectively

I.D. | | | | |

Sleepiness rating:
1= extremely alert
2=
3= alert
4=
5= neither sleepy nor alert
6=
7= sleepy, but no difficulty remaining awake.
8=
9= extremely sleepy, fighting sleep.

Sleep Quality:
1= extremely good
2=
3=
4=
5=
6=
7= extremely poor

Comments

27

UTC Conversion Chart

UTC	South African Standard Time	New York Eastern Daylight Time March 11th 2012 – Nov 4th 2012	New York Eastern Standard Time Nov 4th 2012 – March 10th 2013
00:00	02:00	20:00	19:00
01:00	03:00	21:00	20:00
02:00	04:00	22:00	21:00
03:00	05:00	23:00	22:00
04:00	06:00	00:00	23:00
05:00	07:00	01:00	00:00
06:00	08:00	02:00	01:00
07:00	09:00	03:00	02:00
08:00	10:00	04:00	03:00
09:00	11:00	05:00	04:00
10:00	12:00	06:00	05:00
11:00	13:00	07:00	06:00
12:00	14:00	08:00	07:00
13:00	15:00	09:00	08:00
14:00	16:00	10:00	09:00
15:00	17:00	11:00	10:00
16:00	18:00	12:00	11:00
17:00	19:00	13:00	12:00
18:00	20:00	14:00	13:00
19:00	21:00	15:00	14:00
20:00	22:00	16:00	15:00
21:00	23:00	17:00	16:00
22:00	00:00	18:00	17:00
23:00	01:00	19:00	18:00

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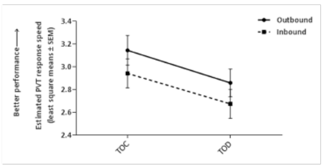
APPENDIX F BROCHURE FOR PARTICIPANTS

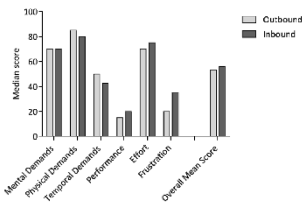
PERFORMANCE ACROSS THE FLIGHT

- Reaction time performance declined across the flight.
- Reaction time performance was better on the outbound leg in comparison to the inbound leg.



WORKLOAD

- No differences in workload were detected between the outbound and inbound flight leg.
- Flight delays, turbulence, medical incidents and major service disruptions were more frequent on the outbound leg in comparison to the inbound leg. This may explain why workload scores were not different between the flight legs.



WHAT CAN YOU DO?

Get as much sleep as possible in the 24 hours before the flight:

- Take an afternoon nap before the outbound leg
  A pre-flight nap be more important if a crewmember is unable to get enough sleep during the outbound leg.
- On the 2nd day of the layover, take a nap during the afternoon or go to bed earlier to increase the amount of sleep in the 24 hrs before the inbound leg

Some crewmembers seem to recover more slowly than others following the ULR trip:

- Prioritize sleep during your days off after the trip

ACKNOWLEDGEMENTS
- All Cabin crew who participated in the study
- Capt Wynand Serfontein
- Research assistants at SAA: Barbie Moonsamy, Carol Myaluza, Ayanda Toti, Beverly Seabi, Heather Marule, Samantha Narisamulu, Carey Bouwer and Masilo Matsoko
- Rosie Gibson, Sophie McCashin, Hannah Timms at the Sleep/Wake Research Centre
- Dr David Darwent, University of Central Queensland, Adelaide, Australia

Sleep/Wake Research Centre
Massey University
Wellington, New Zealand
http://sleepwake.massey.ac.nz

June 2014

South African Airways
A STAR ALLIANCE MEMBER

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Sleep and Performance of Cabin crew on the Johannesburg-New York Ultra Long Range flight

Margo van den Berg
Dr Leigh Signal
Hannah Mulrine
Dr Alex Smith
Prof Philippa Gander

THE ENGINE OF THE NEW NEW ZEALAND

WHY WE DID THE STUDY

The Johannesburg-New York flight, is often longer than 16 hours and is known as a Ultra-Long Range (ULR) flight.

These longer flights may increase fatigue due to longer periods of wakefulness. More time may be needed to recover during the layover and post-trip.

This study focused on the following questions:

- Does Cabin crew sleepiness, fatigue and performance degrade during the course of a JNB-JFK-JNB trip?
- When and how much are Cabin crew sleeping in flight?
- When and how much are Cabin crew sleeping on layovers?
- How many days post trip are required for fatigue and sleep to return to pre-trip levels?

HOW WE DID THE STUDY

The study was reviewed and approved by the independent Massey University Human Ethics Committee (HEC Southern A: application 11/74).

All Cabin Crew flying the JNB-JFK-JNB ULR trips were able to participate. The aim was to recruit 50 Cabin Crew.

Crewmembers:

- Wore an actigraph (to measure sleep) from 3 days before the ULR trip, throughout the trip and during the first 5 days back at home;
- Completed a sleep/duty diary, which contained a pre-study questionnaire (to collect general demographic and sleep information) and was also used to record information about the timing and quality of sleep at home, in-flight and during the layover;
- Rated their fatigue and sleepiness before and after each sleep and at key times during the flight;
- Rated their subjective workload on each flight;
- Completed a 5-minute reaction time test (PalmPVT) pre-flight (before departure), around Top of Climb (TOC) and around Top of Descent (TOD).

WHAT WE FOUND

Fifty five crewmembers provided data.

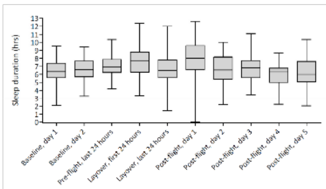
AT HOME

PRE-TRIP:

- Crewmembers averaged 6.5 hours sleep (ranging between 2.1-9.5 hours) before the trip.
  (Baseline days 1 & 2 in Figure below)
- Crew prepared well for the outbound leg:
  - By getting more sleep (on average 7.0 hours) in the 24 hours pre-flight (ranging between 4.2-10.4 hours) and
  - 40% of crewmembers took a pre-flight nap (56% of A crew; 26.7% of B crew).

POST-TRIP:

- Crew obtained more sleep (on average 85 minutes more) on the first day back from the trip and 58% took a post-flight nap.
- From day 2 onwards, crew obtained a similar amount of sleep compared to pre-trip.
- Sleep quality, and subjective sleepiness and fatigue ratings after nighttime sleep on post-trip days did not differ from pre-trip days.
- There was a great deal of variability between individuals. This suggests that some crewmembers recover more slowly than others.



* The figure above displays a boxplot for each of the days. Each boxplot displays the middle 50% of data as a grey box, with the median value indicated by the line in the middle of the box. The ends of the vertical lines (whiskers) represent the minimum (bottom) and maximum (top) values.

ON LAYOVER

- Crew obtained on average 69 minutes more sleep in the first 24 hours of the layover (7.6 hours in total) than at home.
- The amount of sleep in the last 24 hours of the layover was the same compared to sleep at home pre-trip (6.5 hrs).
- Most crewmembers shifted their second night's sleep to the local New York night (so they went to bed later). Sleep was therefore shortened due to the morning sign-on time and/or not being able to stay asleep as a result of their body clock being on JNB time.

IN-FLIGHT

- All crewmembers attempted sleep during their scheduled bunk rest breaks and all crew members obtained some in-flight sleep.
- Overall, crewmembers obtained on average 3.6 hours sleep on the outbound leg and 2.9 hours on the inbound leg.
- Sleep quality did not differ between flight legs.
- The amount and quality of sleep was not associated with age.
- Taking a pre-flight nap did not affect the amount of sleep obtained during the crewmember's first break or total amount of in-flight sleep.
- Crewmembers felt least fatigued and sleepy pre-flight, and became progressively more fatigued and sleepy across the flight.
- Crewmembers felt less fatigued on the outbound leg in comparison to the inbound leg.
- Crewmembers felt more fatigued and sleepy at TOD when they had been awake for longer.

APPENDIX G ACTIGRAPHY SCORING PROTOCOL

In Actiware 5 (Philips Respironics®), ensure the Wake Threshold Selection is set to "Medium". Set the Actogram start hour to 12:00 am (so that the timeline is from midnight to midnight). On the right of the screen, set the Actogram Length to '3' (3 days) and the Activity Scale Max to '1000'.

The actigraphy is recorded in UTC time (Coordinated Universal Time);

- It is possible that sleep times written in the diary's sleep boxes and/or on the time lines are in South African time (UTC+2hrs).
- For layover sleep in New York, check if sleep times written in the diary were UTC or local NY time (NY time is UTC-5 in winter and UTC-4 (= day light saving) in summer; Daylight saving began 11 March 2012 and ended 4 November 2012; In 2013, DLS starts on 10 March and will end 2 Nov 2013.

Where sleep is split, score as one sleep if there is less than, or equal to 10 minutes between event markers (end marker sleep 1 and start marker sleep 2). Score as two separate sleeps when there is more than 10 mins between end- and start times.

Rest Interval start- and end times are set by the researcher using three sources of information:

1. Change in actigraphy data
2. Event marker
3. Sleep diary

Compare all three sources of information and when information does not match:

- Actigraphy and event marker match, diary does not: Use actigraphy and event marker.

- Actigraphy and diary match, event marker does not: Use actigraphy and diary

- Event marker and diary match, actigraphy does not: Use event marker and diary

In case none match:

- Actigraphy data primary source, then event marker, followed by sleep diary

When the watch was off during a sleep period, insert an ‘Excluded Interval’, using the bedtime and get up time recorded in the diary as start- and end time of the Excluded interval (these times will be included in the export file for determining Time in Bed).

To assess the reliability of manual selection of rest intervals, 20% of files are to be double scored by a second independent trained researcher. Any discrepancies of more than 15 minutes for either ‘start time’ or ‘end time’ of the rest interval need to be flagged and re-analysed, and checked by a third independent person.

Report the proportion of start times and proportion of end times where the discrepancy between scorers was greater than 15 minutes, as well as the overall Agreement rate (agreement being classed as 15 minutes or less difference between scorers).

APPENDIX H CRITERIA FOR INCLUDING PVT DATA

PVT tests were completed three times in association with each flight leg (pre-flight, at TOC and at TOD). On some occasions, tests were not completed close enough to the specified times in flight and were thus excluded from analyses in order ascertain that data from tests completed at non-standard times did not mask, or confound changes in performance.

H.1 Timing of PVT tests

H.1.1 At top-of-climb (TOC)

Cabin crew were briefed to complete the TOC test just after take-off, before the seat belt sign was switched off. In order to determine the earliest clock time at which the TOC test could be completed after take-off, the take-off time was estimated as blocks-off time plus 15 minutes taxi time for both the outbound and inbound flight. To determine the latest clock time at which the TOC test could be completed after take-off, the take-off time was estimated as blocks-off time plus 20 minutes as the maximum taxi time in JNB and as blocks-off time plus 45 minutes as the maximum taxi time at JFK. Therefore, any TOC tests completed less than 15 minutes after blocks-off or more than 110 minutes after blocks-off time on the outbound leg were excluded. Similarly, any TOC test completed less than 15 minutes after blocks-off or more than 135 minutes after blocks-off time on the inbound leg were excluded.

H.1.2 At top-of-descent (TOD)

Cabin crew were briefed to complete the TOD test at the end of the last meal service, within 90 minutes before landing. Landing time was estimated as blocks-on time minus 10-15 minutes taxi time. Any test completed less than 10 minutes before blocks-on (i.e. after landing) or more than 105 minutes (90+15 minutes taxi time) before blocks-on time were excluded.

The number of tests that were included and excluded are summarized in Table H-1.

Table H-1 Number of PVT tests included and excluded from analyses based on pre-defined criteria

Test time	Inclusion criteria	Missing (n)	Included (n)	Excluded (n)	Reasons for exclusion
Pre-flight [a]	Within 270 minutes prior to departure	21	86	3	completed too late, after Blocks-off
TOC	Within 90 minutes after take-off	18	65	27	7 tests were completed too early; 20 tests were completed too late
TOD	At the end of the last meal service, within 90 minutes before landing	19	72	19	Completed too late

[a] The pre-flight test was subsequently excluded from analyses

H.2 Influence of testing environment

As illustrated in Figure H-1 below, performance on the pre-flight PVT on the outbound sector was worse than performance on the subsequent TOC test and TOD test. In contrast, performance on the pre-flight PVT test on the inbound leg was better than performance on the subsequent tests.

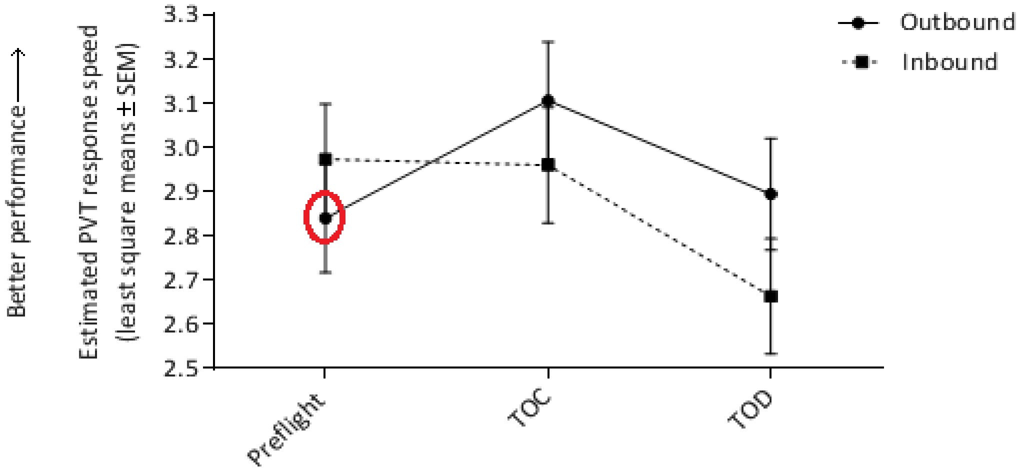


Figure H-1 Mean PVT response speed prior the outbound flight in comparison to other test times

The outbound pre- flight test was performed during the early evening (local time) which in laboratory studies has been shown to be the optimum time in the circadian cycle for PVT performance. The subsequent TOC test was performed approximately 2 hours after the pre-flight test, when PVT performance is not expected to improve due to the influence of circadian timing. The observed improvement in performance from pre-flight to TOC therefore cannot be explained by circadian rhythm in PVT performance.

None of the crewmembers obtained sleep between the pre-flight test and TOC test, therefore the observed improvement in PVT performance cannot be explained by recovery from sleep loss.

No information was collected on caffeine intake. Caffeine can affect alertness within one hour after ingestion, improving performance and reducing subjective sleepiness (Lim & Dinges, 2008). If the observed improvement in PVT performance from pre-flight to TOC were indeed due to increased alertness after caffeine intake, it would be expected that sleepiness ratings were lower at TOC compared to pre-flight. However, there was no reduction observed in subjective sleepiness from pre-flight to TOC.

As illustrated in Figure H-2, more lapses were made during the outbound pre-flight test in comparison to the subsequent tests on this leg, with most crewmembers (93.5%) lapsing at least once. The context in which a PVT test is completed can influence the results. Distractions during the test can result in PVT lapses. It is not possible to distinguish lapses caused by distraction from lapses due to fatigue.

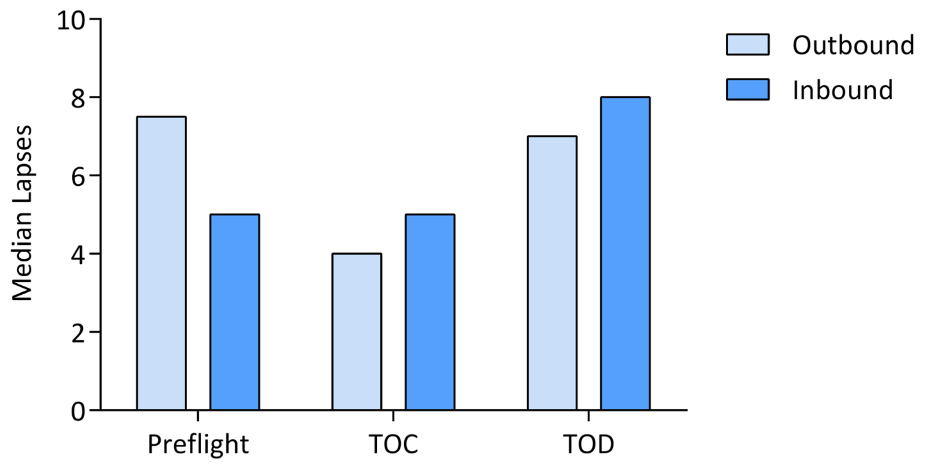


Figure H-2 Median PVT Lapses pre-flight in comparison to subsequent test times

Based on these considerations, the outbound pre-flight PVT test was deemed invalid. To enable comparisons between flight legs, both the outbound and inbound pre-flight tests were excluded from the data analyses.

APPENDIX I ETHICAL APPROVAL FOCUS GROUP STUDY

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

7 August 2013

Margo van den Berg
Sleep/Wake Research Centre
WELLINGTON

Dear Margo

Re: HEC: Southern A Application – 13/45
Cabin crew sleep and fatigue

Thank you for your letter dated 2 August 2013.

On behalf of the Massey University Human Ethics Committee: Southern A I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Dr Brian Finch, Chair
Massey University Human Ethics Committee: Southern A

cc Prof Philippa Gander
Sleep/Wake Research Centre
WELLINGTON

Dr Leigh Signal
Sleep/Wake Research Centre
WELLINGTON

Massey University Human Ethics Committee
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E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz **www.massey.ac.nz**

APPENDIX J CONFIDENTIALITY FORM

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Focus group Study

Cabin Crew Sleep and Fatigue

CONFIDENTIALITY AGREEMENT

I .... (Full Name - printed)

agree to keep confidential all information concerning the project ....

....

.... (Title of Project).

I will not retain or copy any information involving the project.

Signature: .... **Date:** ....

Confidentiality Agreement – Cabin Crew Focus groups – June 2013 Page 1 of 1

Sleep/Wake Research Centre – Moe Tika, Moe Pai
PO Box 756, Wellington 6140, Aotearoa / New Zealand **T** +64 4 380 0603 **E** swrc@massey.ac.nz **http://sleepwake.massey.ac.nz**

APPENDIX K ADVERTISEMENT FOCUS GROUP STUDY

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

SLEEP~WAKE research centre
MOETIKA~MOE PAI

VOLUNTEERS NEEDED

for small group discussion on

Cabin Crew Sleep and Fatigue

Description of Project: The study aims to understand how Cabin crew feel about their sleep and fatigue, and how fatigue might affect how safely and well they can do their job. During a discussion with a small group of SAA Cabin crew (called focus groups), you'll be asked what you think about:

- what causes fatigue
- what happens when you get fatigued
- how your work is affected by fatigue
- how you and SAA manage fatigue
- what could be changed to reduce fatigue during flights

You will be asked about fatigue during Short-haul, Long-haul as well as Ultra-Long haul operations.

Who can take part? All Cabin Crew who have flown the JNB-JFK-JNB ULR trip are able to participate.

When? In February 2014. Arrangements will be made with rostering so that you can attend a focus group during work time.

Remuneration: Participants will receive a gift voucher to the value of ZAR500.

To learn more: Contact :

Masilo Matseke: MasiloMatseke@flysaa.com Cel: 079 145 2501 Office: 011 978 3029
or
Margo van den Berg: M.J.vandenberg@massey.ac.nz

Closing date: Applications must be received by 15 December 2013

This study forms part of Margo van den Berg's doctoral research, which is looking at how to best manage fatigue for Cabin crew. Her work is supervised by Dr. Leigh Signal and Prof. Philippa Gander at the Sleep/Wake Research Centre, Massey University, Wellington, New Zealand.
This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 13/45.

APPENDIX L PARTICIPANT INFORMATION SHEET FOCUS GROUP STUDY

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

INFORMATION SHEET

Cabin Crew Sleep and Fatigue

You are invited to take part in a small group discussion. We would like to hear about your experiences of fatigue during short-haul, long-haul and ultra-long haul operations.

This study forms part of Margo van den Berg's doctoral research, which is looking at how to best manage fatigue for Cabin crew. Her work is supervised by Dr. Leigh Signal and Prof. Philippa Gander at the Sleep/Wake Research Centre, Massey University, Wellington, New Zealand. Their contact details can be found below.

The present study aims to understand how Cabin crew feel about their sleep and fatigue, and how fatigue might affect how safely and well they can do their job. You will be asked what you think during a discussion with a small group of SAA Cabin crew (called focus groups). You will be asked what you think about:

- what causes fatigue
- what happens when you get fatigued
- how your work is affected by fatigue
- how you and SAA manage fatigue
- what could be changed to reduce fatigue during flights

You will be asked about fatigue during Short-haul, Long-haul as well as Ultra-Long haul operations.

Who can take part?
All Cabin Crew who have flown the JNB-JFK-JNB ULR trip are able to participate.

Each focus group will include up to 8 Cabin crew and will be run by two facilitators who are members of the research team. The session will take the form of a semi-structured discussion. Focus groups will be audio-taped and transcribed and analysis will involve reviewing the transcripts for information to increase understanding about the factors and consequences of fatigue in relation to fatigue-related risk inflight.

What is involved if you decide to participate?
If you decide to be in a focus group:

- You will be asked to attend a focus group session at South African Airways. Arrangements will be made with rostering so that you can attend a focus group during work time.

Sleep/Wake Research Centre – Moe Tika, Moe Pai
PO Box 756, Wellington 6140, Aotearoa / New Zealand **T** +64 4 380 0603 **E** swrc@massey.ac.nz **http://sleepwake.massey.ac.nz**

- The session will last no more than 2 hours, and it will be facilitated by Margo van den Berg from the Sleep/Wake Research Centre and by a research assistant at South African Airways.
- At the start of the focus group you will be asked to complete a short questionnaire, asking demographic information (your age, gender and work experience).
- Discussion at the group will be audio-taped and transcribed. You will be supplied with a copy of the transcribed session. You can amend your contributions, have them withdrawn, or consent to their use for review.
- The results will be reported as grouped information. Direct quotes may be used but no material which could identify you will be used in any reports on this study.
- Refreshments will be provided.
- You will receive a gift voucher with the value of ZAR500 as a token of appreciation for your time.

Participation
You are under no obligation to accept this invitation. Your decision to participate or not to participate will have no effect on your employment. If you decide to participate, you have the right to:

- Decline to answer any particular question.
- Make no comments on the discussion items raised.
- Withdraw from the focus group, either during the session or upon receipt of the transcript copy.
- Ask any questions about the study of focus group at any time during participation.
- Provide information on the understanding that your name will not be used unless you give permission
- Be given access to a summary of the project findings when it is concluded.

What do I do now?
If you choose to participate in the focus group after reading this information sheet, please complete the attached consent form and return it to Masilo Matseke. Only names and contact details of those who agree to participate will be retained.

Committee Approval Statement
This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 13/45. If you have any concerns about the conduct of this research, please contact Dr Brian Finch, Chair, Massey University Human Ethics Committee: Southern A, telephone 06 350 5799 x 84459, email humanethicsoutha@massey.ac.nz.

Project Contacts
If you have any further questions about this study please do not hesitate to contact us at the below phone number, or by e-mail.

Margo van den Berg
m.j.vandenberg@massey.ac.nz
ph: +64 8015799 ext 63259

Dr. Leigh Signal
t.l.signal@massey.ac.nz
ph: +64 8015799 ext 63257

Prof. Philippa Gander
p.h.gander@massey.ac.nz
ph: +64 8015799 ext 63256

Masilo Matseke
MasiloMatseke@flysaa.com
Cel: 079 145 2501
Office:011 978 3029

APPENDIX M CONSENT FORM FOCUS GROUP STUDY

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Cabin Crew Sleep and Fatigue

FOCUS GROUP PARTICIPANT CONSENT FORM

- I have read the Information Sheet dated November 2013 and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.
- I understand that participation in the focus group is voluntary and that I may withdraw from the group at any time.
- I understand that participation in this focus group is confidential. Direct quotes may be used but no material which could identify me will be used in any reports on this study.
- I agree not to disclose anything discussed in the focus group.
- I understand that a transcript of the focus group session will be supplied to me, in which I can amend, withdraw or give consent for my contribution to be used for analysis.
- A gift voucher with a value of ZAR500 will be given to me at the start of the focus group session as a token of appreciation for my time.
- I agree to participate in this study under the conditions set out in the Information Sheet.
- I have had sufficient time to consider whether to take part.
- I know whom to contact if I have any questions about the study.
- This consent form will be held for a period of five (5) years.

Signature: .... **Date:** ....

Full Name - printed ....

Consent Form – Cabin Crew Focus groups– November 2013 Page 1 of 1

Sleep/Wake Research Centre – Moe Tika, Moe Pai
PO Box 756, Wellington 6140, Aotearoa / New Zealand **T** +64 4 380 0603 **E** swrc@massey.ac.nz **http://sleepwake.massey.ac.nz**

APPENDIX N DEMOGRAPHIC QUESTIONNAIRE

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

SLEEP~WAKE research centre
MOETIKA~MOE PAI

Cabin Crew Sleep and Fatigue
Demographic Questionnaire

1 What is your age?

☐☐ years

2 What gender are you?

1 ◯ Male 2 ◯ Female

3 Which position do you normally fly?

Cabin Crew 1 ◯ Purser 2 ◯ Senior Purser 3 ◯

4 **How long have you been working as Cabin Crew?**
Total time in all airlines you have worked for

☐☐ years ☐☐ months

5 On average, how many hours per month do you work?

☐☐☐ hours

6 **In total, how long have you been flying short-haul?**
Flights up to 5 hours

☐☐ years ☐☐ months

7 Are you currently flying short-haul?

1 ◯ Yes 2 ◯ No → go to **8**

7b If yes, what percentage of your work time is short haul?

☐☐ %

8 **In total, how long have you been flying long-haul?**
Flights longer than 5 hours and up to 16 hours

☐☐ years ☐☐ months

9 Are you currently flying long-haul?

1 ◯ Yes 2 ◯ No → go to **10**

9b If yes, what percentage of your work time is long-haul?

☐☐ %

10 **In total, how long have you been flying ULR?**
Ultra-long range: flights over 16 hours

☐☐ years ☐☐ months

11 Are you currently flying ultra-long haul (ULR)?

1 ◯ Yes 2 ◯ No → go to **12**

11b If yes, what percentage of your work time is ULR?

☐☐ %

12 Did you previously take part in the JNB-JFK ULR study?

1 ◯ Yes 2 ◯ No

Thank you

APPENDIX O INTERVIEW SCRIPT

Cabin Crew Focus groups Interview Script

[prior to start of recording, greet the participants as they arrive, offer refreshments, and ask participants to complete the Demographics questionnaire and hand them each a gift voucher] [allow 15 mins]

Introduction: [5 mins]

Thank you all for coming to this focus group. My name is Margo van den Berg and I'm from the Sleep/Wake Research Centre at Massey University in New Zealand. Masilo Matseke, who I think you have met before, is assisting with this research project and he will be taking notes today, but he will not take part in the discussion.

First of all just a couple of house-keeping things: the bathrooms are [.....], the emergency exit is ...[...] and please help yourself to more refreshments during the discussion if you like.

I am conducting these focus groups as part of my PhD research, which is looking at how to best manage fatigue for Cabin crew.
There is a small amount of research that shows that fatigue is widely experienced among Cabin Crew, but on the whole, Cabin Crew have not been studied very often.

Fatigue at work is affected by what you do at work but also by what you do outside of work.

In order to manage the risks of fatigue during a flight, we need to learn more about what is causing fatigue for Cabin Crew and how it might be affecting their ability to do their job safely.

This *focus group* study is to find out what <u>you</u> think about fatigue, what causes it, whether it affects how you do your job and how you manage fatigue before, during and after a flight.

The findings of this study will help improve how fatigue is being managed for Cabin Crew.

Your comments are completely confidential and your name will not appear in any results.
If you no longer wish to be part of this discussion, you are completely free to leave at any time.

The format of this group discussion is informal and I will simply be asking for different ideas and opinions on this topic, so please feel comfortable to say what you really think.
There are no right or wrong answers and so please also respect the views of the others.

It is important that everyone has a chance to share their ideas, so I may sometimes encourage you to share your ideas, or, if you are speaking more than others I may ask that someone else has an opportunity to comment. We have only 2 hours to cover a quite a large topic and I'd like everyone to have equal opportunities to comment.

As you can see there is an audio recorder in the middle of the table to record all information correctly, and I will start it shortly.
Because we don't want to miss anything that is said, it's important that only one person talks at a time.
And importantly, because this is a group discussion, please talk to each other, not just to me.

At this stage, are there any questions or concerns?
Okay, I will now start the recording and then we'll begin.

Warm-up [5 mins]
As an introduction, let's go around the group and perhaps you could give your first name and tell us in one sentence what your favorite layover city is and why [ask short response question; not a discussion question].

Great! We will now start with the main discussion around fatigue, and I want you to think about your current situation, not how things were several years ago.
When thinking about work and fatigue, also consider any differences that might exist between types of trips or flights, such short-haul, long-haul or ultra-long range.

This poster here is a guide to the key questions.

Key content section [90 mins; allows approx. 10 mins discussion per question; use poster as guide]

1. Firstly, when you are at **home,** what makes you fatigued?
   (Probes: Family demands, inability to sleep (jetlag; off duty timing, noise), commuting time, social activities, level of fitness, age

2. When you are at **work** what makes you fatigued?
   *(Probes: **Roster -** Irregular/long duty days, early starts, day vs night flights, standby, planned vs actual duty periods, roster changes, sequence of shorthaul/longhaul/ULR in a monthly roster, #of days off; frequency of time zone changes; **Tasks at work –** on short-haul, long-haul, ULR; **Work environment -** timing of in-flight rests, one vs two breaks, quality of rest facilities; noise/disturbances at layover hotel**; Personal factors -** level of fitness, age, level of work experience.*

3. How does fatigue affect you, when you are at **home**?
   (Concentration, maintaining focus, sleep quality, digestion, health, mood, stress, family time/responsibilities, study, social activities)

4. How does fatigue affect you, when you are at **work**?
   (*Concentration, maintaining focus, mood, stress, communication, workload, what aspects of workload, work performance, absenteeism, job satisfaction. driving home after work)*

5. Are there **safety**-related tasks at work that are affected by your fatigue?
   (arming/disarming doors, safety checks, passenger safety, passenger risk assessment, communication)B

6. How do you currently manage your fatigue at **home**? (what strategies do you use to cope, countermeasures)
   Probes:
   Sleep timing, sleep aids, napping, exercise, caffeine, diet,

7. How do you currently manage your fatigue at **work**?
   (social interaction; fatigue reporting, scheduled & unscheduled rest opportunities, training)

8. If you think that fatigue is a safety concern in flight, what do you think could be changed for Cabin crew?

9. ***Optional if time permits [allow 15 mins]***: As part of the airline's Fatigue Risk Management System, monitoring crew members' fatigue during a flight operation is sometimes required. A set of measures recommended for this purpose include wearing an activity monitor to record sleep patterns, and completing subjective sleepiness & fatigue ratings and a 5-minute reaction time test (called the PalmPVT test). In the JNB-JFK ULR study, we asked Cabin crew to do the PalmPVT test preflight after sign-on, before the first meal service and at the end of the last meal service.

   Completing the test *without distractions* has shown to be difficult and I would like to find out what could be done to help improve this.

   Do you have any suggestions?

Closing [5 mins]

We are now reaching the end of this discussion. Does anyone have any further comments to add before we conclude this session?

I would like to thank you all very much for your participation. Your experiences, opinions and thoughts are a very valuable source of information that will contribute to improving fatigue-risk management for Cabin Crew.

To explain what will happen next:

the recording of today's discussion will be transcribed over the next month or so.
Once completed, I will email you a copy of the transcript. Each of your names will have been replaced with a letter of the alphabet, and in my email to you, I will tell you which letter you are, so that you can check and/or edit your contribution if you wish. In the same email, I will include a release form, for you to sign if you are happy to have your contribution included in the analyses. You can return a signed form either by scanning it, or by taking a photo and emailing this back to me.

You will be sent a copy of the report at a later stage and you'll have the opportunity to comment on that before it is published.

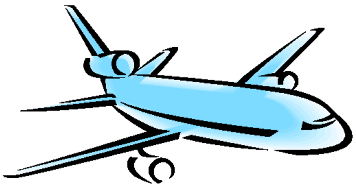
Once again, thank you so much for taking part!

APPENDIX P VISUAL PROMPTS POSTER

Fatigue

Causes & Effects

At home



At work

Safety-related risk at work

Managing fatigue

APPENDIX Q AUTHORITY FOR THE RELEASE OF TRANSCRIPTS

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Focus Group Study

Cabin Crew Sleep and Fatigue

AUTHORITY FOR THE RELEASE OF TRANSCRIPTS

I confirm that I have had the opportunity to read and amend the transcript of my contribution to the focus group discussion.

I agree that the edited transcript and extracts from this may be used in reports and publications arising from the research.

Signature: .... **Date:** ....

Full Name - printed ....

Authority for Release of Transcripts – Cabin Crew Focus groups - August 2013 Page 1 of 1

Sleep/Wake Research Centre – Moe Tika, Moe Pai
PO Box 756, Wellington 6140, Aotearoa / New Zealand T +64 4 380 0603 E swrc@massey.ac.nz **http://sleepwake.massey.ac.nz**

APPENDIX R INITIAL THEMATIC MAP

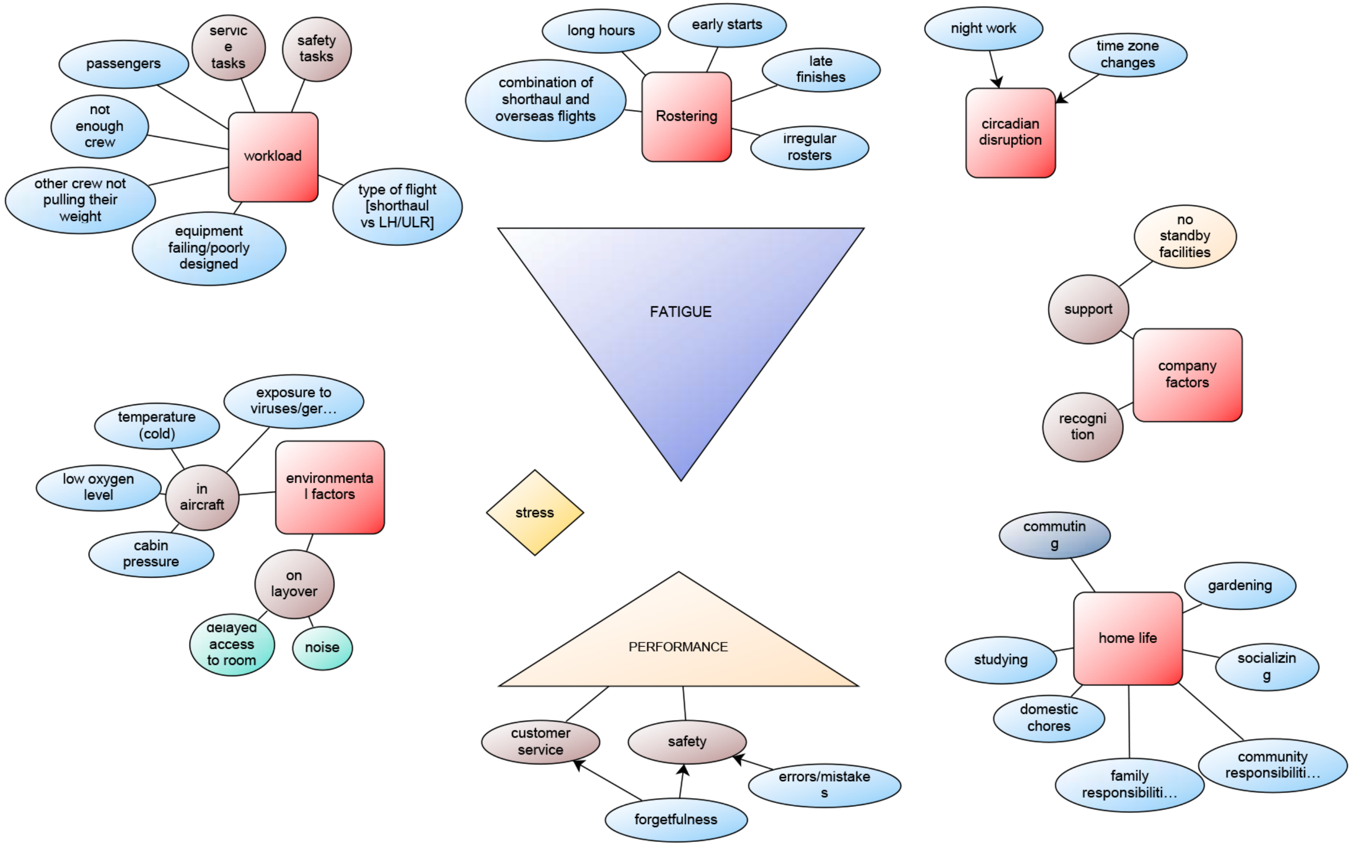


Figure R-1 Initial thematic map

APPENDIX S FINALIZED THEMES AND SUB-THEMES

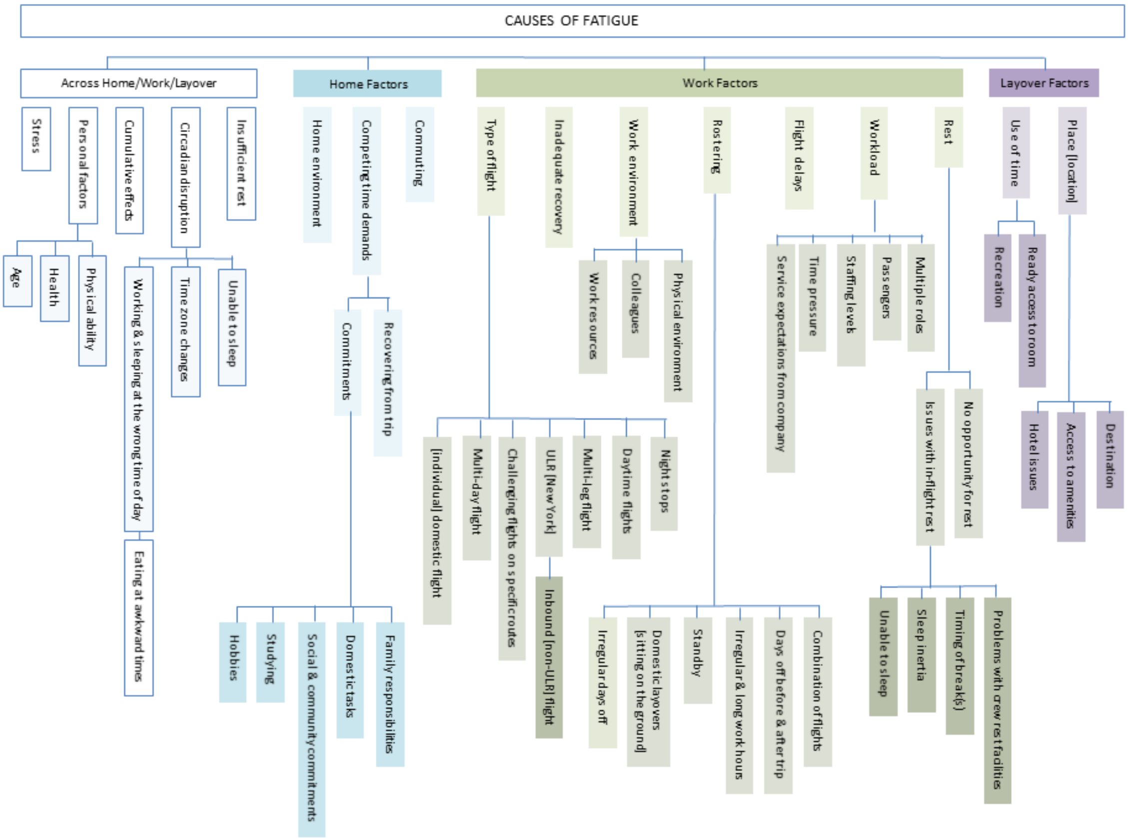


Figure S-1 Causes of fatigue as reported by cabin crew, displaying themes, sub-themes and codes

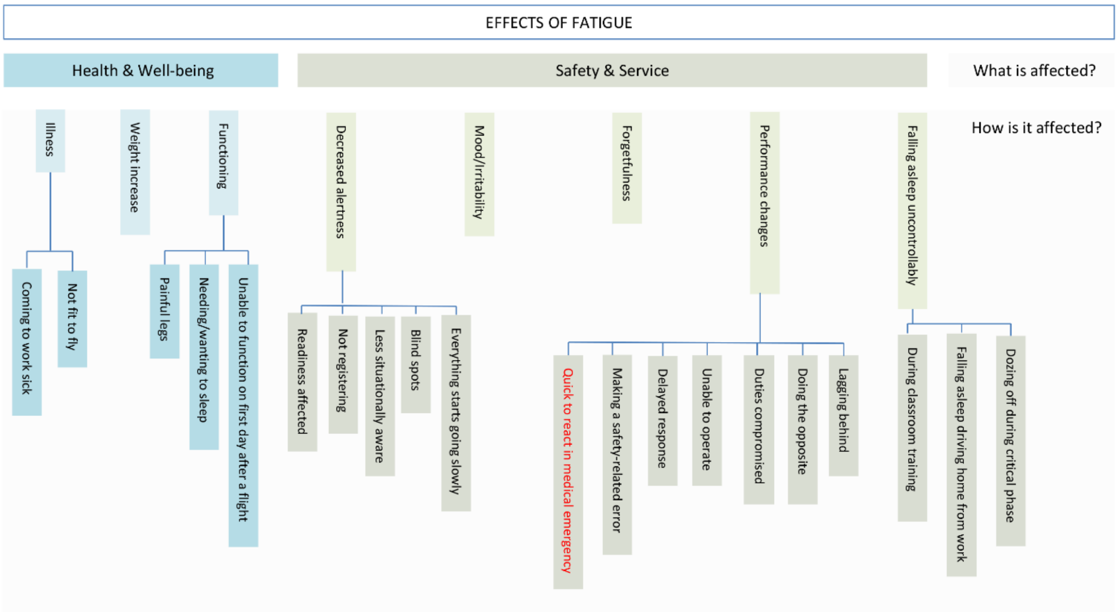


Figure S-2 Effects of fatigue as reported by cabin crew, displaying themes, sub-themes and codes

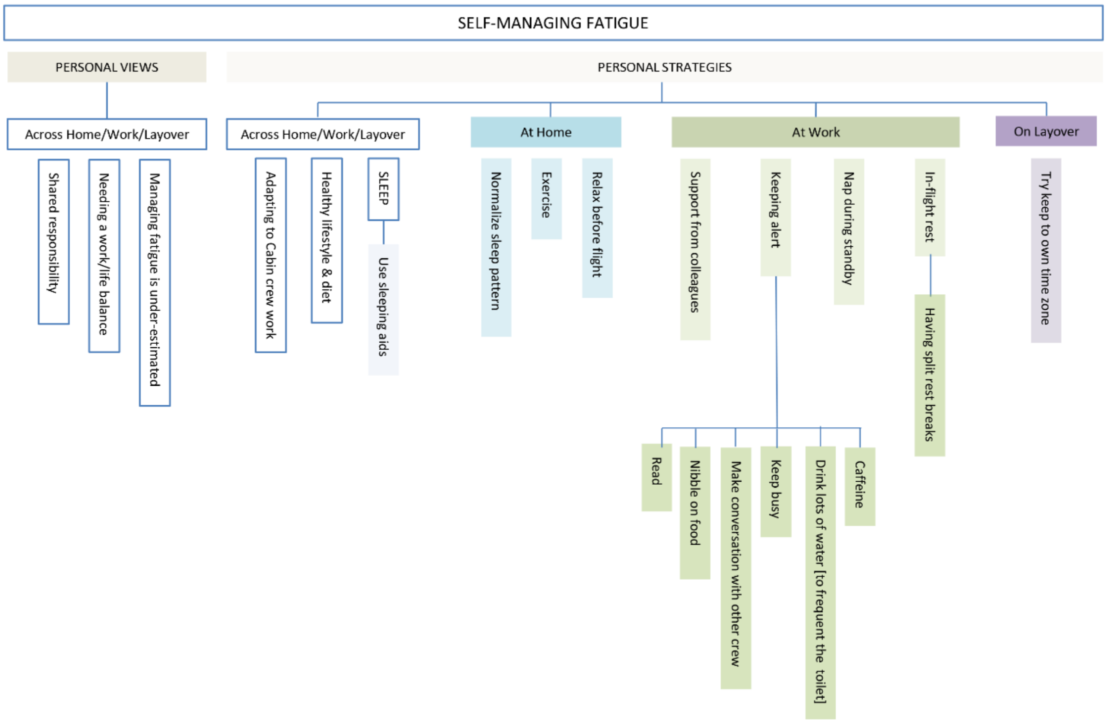


Figure S-3 **Personal strategies and views of self-managing fatigue as reported by cabin crew, displaying themes, sub-themes and codes**

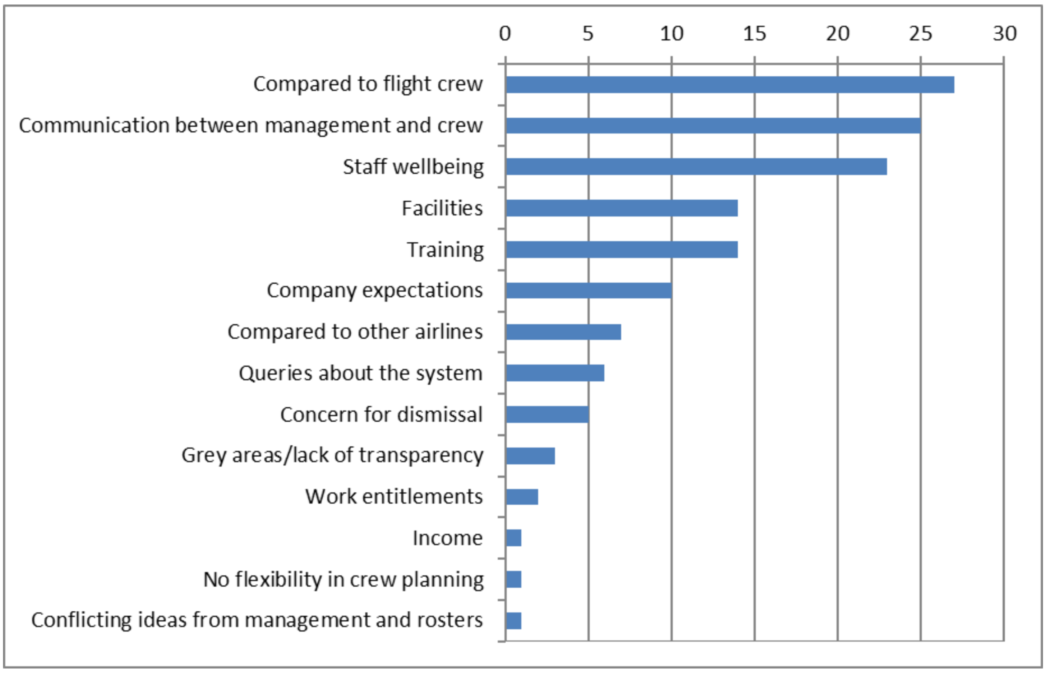


Figure S-4 Company support and other work aspects contributing to fatigue, as reported by cabin crew

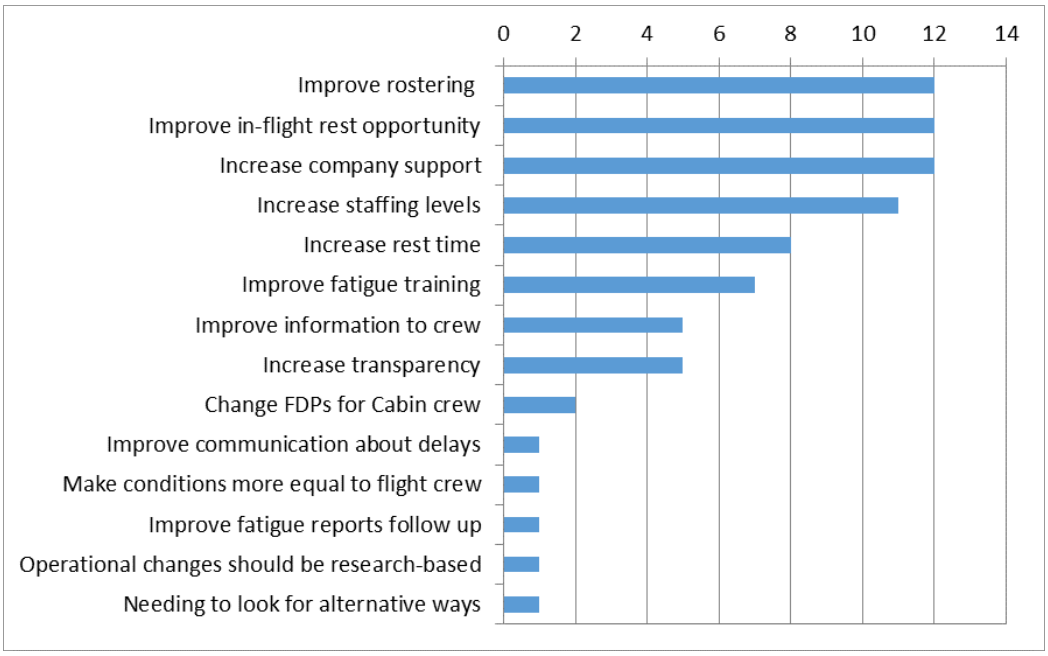


Figure S-5 Cabin crews' recommendations for improving their fatigue risk management

APPENDIX T PARTICIPANT COMMENTS ON FOCUS GROUP STUDY FINDINGS

One participant provided comment in response to the draft report for management at South African Airways:

"*The flight between Johannesburg and New York is very long, even for a passenger. No matter how long the rest period is that you get on board, the crew is not alert enough by the third part of the flight. It could become a problem as crew must be alert at all times.*"

APPENDIX U DESCRIPTIVE STATISTICS FOR CHAPTER 3

Table U-1 Total sleep time (minutes) at home pre- and post-flight, and on layover

Time period	Mean	SD	Median	Range	N
Baseline day 1 [a]	383	88	379	125 – 572	49
Baseline day 2	394	85	399	197 - 565	53
Pre-flight, last 24 hours [bc]	421	79	417	251 – 621	54
Layover, first 24 hours	456	122	463	199 – 743	54
Layover, last 24 hours	388	103	389	85 - 719	55
Post-flight day 1[de]	472	131	481	0 – 756	51
Post-flight day 2	399	106	393	130 – 600	51
Post-flight day 3	402	97	409	206 – 666	51
Post-flight day 4	364	79	378	134 – 520	48
Post-flight day 5 [f]	378	111	364	155 – 621	30

[a] Includes 1 outlier; [b] Includes 1 outlier; [c] 22 crewmembers had a nap prior to the outbound flight, which is included in this 24-hour period; [d] Includes one participant who did not sleep on this day; [e] 11 crewmembers had a nap after landing which began prior to the post-flight day 1 time period starting at noon; [f] Excludes 11 crewmembers who started a new work regime and 14 crewmembers had no data on this day.

Table U-2 Samn-Perelli Crew Status Check fatigue ratings at key times on outbound and inbound flights

Leg	Time	Mean	SD	Median	Range	N
Outbound						
	Pre-flight	2.1[ab]	1.3	2.0	1-7	51
	TOC	2.5[a]	1.5	2.0	1-5	47
	TOD	3.9[a]	1.7	4.0	1-7	44
	After Landing	4.5[a]	1.7	5.0	1-7	50
Inbound						
	Pre-flight	2.6[a]	1.5	2.0	1-5	46
	TOC	3.0[a]	1.6	3.0	1-6	44
	TOD	4.6[a]	1.5	5.0	2-7	43
	After Landing	5.0[ac]	1.4	5.0	1-7	44

[a] Data non-normally distributed; [b] Includes 1 outlier; [c] Includes 5 outliers

Table U-3 Karolinska Sleepiness Scale ratings at key times on outbound and inbound flights

Leg	Time	Mean	SD	Median	Range	N
Outbound						
	Pre-flight	2.5[ab]	1.4	2.0	1-7	48
	TOC	3.0[a]	1.9	3.0	1-7	46
	TOD	4.6[a]	2.0	5.0	1-8	43
	After Landing	5.6[a]	2.1	6.0	1-9	50
Inbound						
	Pre-flight	3.1[a]	1.6	3.0	1-7	46
	TOC	3.5[a]	1.7	3.0	1-7	44
	TOD	5.3	1.9	5.0	1-9	43
	After Landing	5.9[a]	1.9	6.0	1-9	44

[a] Data non-normally distributed; [b] Includes 1 outlier.

Table U-4 PVT response speed at key times on outbound and inbound flights

Leg	Time	Mean	SD	Median	Range	N
Outbound						
	TOC	3.1	0.9	3.2	1.4 – 5.1	31
	TOD[a]	2.8	0.8	2.8	0.9 – 4.3	39
Inbound						
	TOC[b]	2.9	0.7	3.0	0.7 – 4.1	34
	TOD	2.7	0.7	2.7	1.3 – 4.0	33

[a] Includes 2 outliers; [b] Includes 1 outlier.

Table U-5 Fastest 10% of PVT responses for Cabin crew at TOC and TOD on outbound and inbound flights (responses/sec)

Leg	Time	Mean	SD	Median	Range	N
Outbound						
	TOC	4.3	1.0	4.3	2.1 – 6.1	31
	TOD	4.2	0.9	4.1	2.2 – 5.8	39
Inbound						
	TOC[ab]	4.1	0.8	4.2	1.3 – 5.5	34
	TOD	3.9	0.8	3.8	2.1 – 5.4	33

[a] Data not normally distributed; [b] Includes 1 outlier.

Table U-6 Slowest 10% of PVT responses for Cabin crew at TOC and TOD on outbound and inbound flights (responses/sec)

Leg	Time	Mean	SD	Median	Range	N
Outbound						
	TOC	1.6	1.0	1.5	0.3 – 4.0	31
	TOD	1.3	0.8	1.1	0.2 – 3.1	39
Inbound						
	TOC	1.5	0.8	1.5	0.2 – 3.0	34
	TOD[a]	1.1	0.7	0.9	0.3 – 2.6	33

[a] Data not normally distributed.

Table U-7 Number of lapses on the PVT for Cabin crew at TOC and TOD on outbound and inbound flights (responses/sec)

Leg	Time	Mean	SD	Median	Range	N
Outbound						
	TOC[ab]	9.0	12.2	4.0	0 – 41	31
	TOD[ab]	10.4	10.0	7.0	0 – 38	39
Inbound						
	TOC[ac]	8.1	9.1	5.0	0 – 38	34
	TOD[ad]	11.6	10.2	8.0	0 – 41	33

[a] Data not normally distributed; [b] Includes 4 outliers; [c] Includes 2 outliers; [d] Includes 3 outliers.

Table U-8 Post-Sleep Samn-Perelli fatigue ratings after main sleeps on baseline and post-trip days

Time period	Mean	SD	Median	Range	N
Baseline (day 1 & 2)[a]	2.9	1.5	3.0	1 – 7	91
Post-flight day 1[a]	3.1	1.4	3.0	1 – 5	41
Post-flight day 2[a]	3.1	1.5	3.0	1 – 6	39
Post-flight day 3[a]	3.0	1.4	3.0	1 – 6	45
Post-flight day 4[a]	3.2	1.4	3.0	1 – 6	42
Post-flight day 5[a]	2.9	1.3	3.0	1 – 5	31

[a] Data not normally distributed.

Table U-9 Post-Sleep Karolinska Sleepiness Scale ratings after main sleeps on baseline and post-trip days

Time period	Mean	SD	Median	Range	N
Baseline (day 1 & 2)[ab]	4.0	2.0	3.0	1 – 9	91
Post-flight day 1[a]	4.0	2.1	3.0	1 – 8	42
Post-flight day 2[ac]	3.7	1.9	4.0	1 - 9	39
Post-flight day 3[a]	3.6	2.0	3.0	1 - 9	45
Post-flight day 4[a]	3.7	1.8	3.0	1 - 8	41
Post-flight day 5[ad]	3.4	1.5	3.0	1 - 7	31

[a] Data not normally distributed; [b] Includes 2 outliers; [c] Includes 1 outlier; [d] Includes 6 outliers.

APPENDIX V EVALUATING CREWMEMBERS' PRE-FLIGHT STATUS

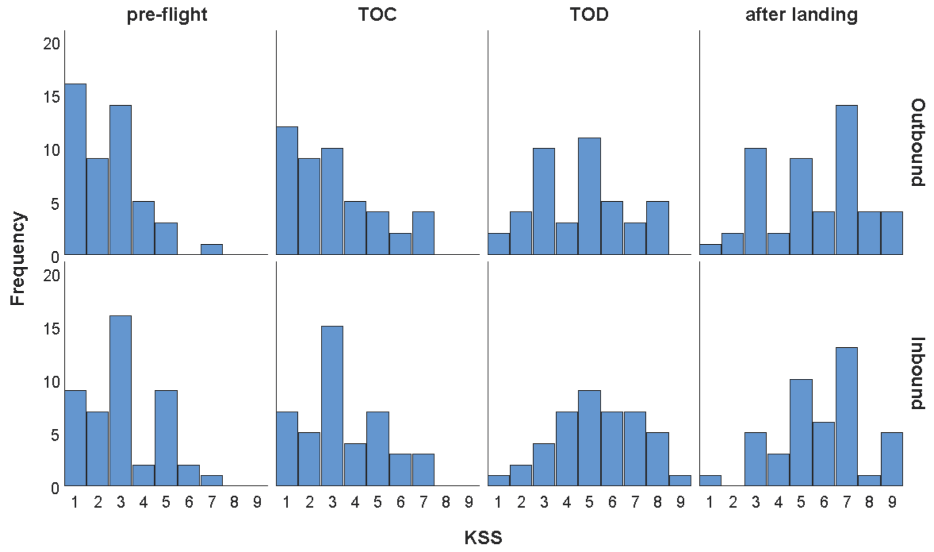


Figure V-1 Frequencies of Karolinska Sleepiness Scale ratings at key times on outbound and inbound flights

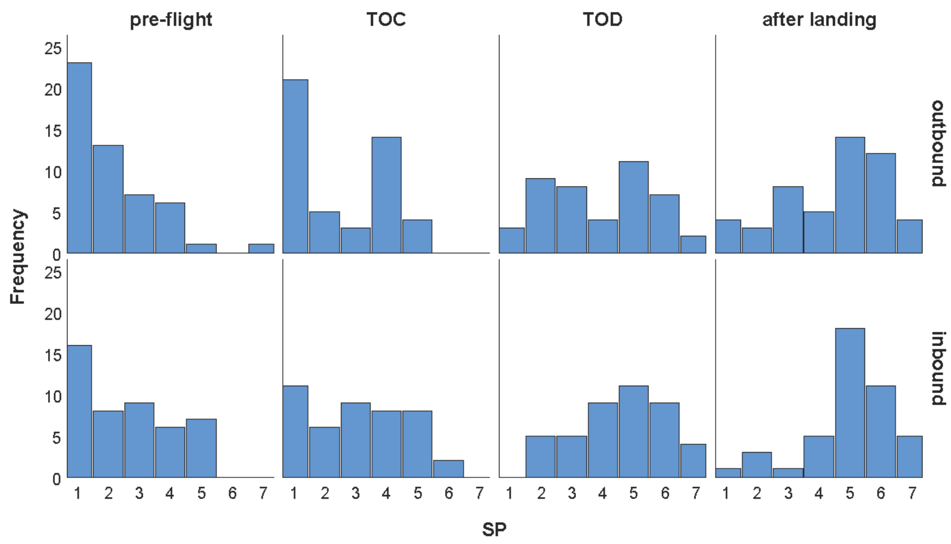


Figure V-2 Frequencies of Samn-Perelli Crew Status Check ratings at key times on outbound and inbound flights

APPENDIX W PROPORTION OF THE FLIGHT AVAILABLE FOR REST

Table W-1 Proportion of the flight available for rest for cabin crew and flight crew on the JNB-JFK-JNB ULR route

	Cabin crew (N=55)		Flight crew (N=52)	
	Outbound	**Inbound**	**Outbound**	**Inbound**
Break duration (hrs) Mean (SD)	5.4 (0.5)	4.6 (0.5)	7.3 (0.3)	6.3 (0.8)
Flight duration (hrs) Mean (SD)	15.9 (0.4)	14.7 (0.3)	16.5 (0.3)	14.6 (0.2)
% rest Mean (SD)	33.96 (3.14)	31.55 (3.87)	44.32 (1.99)	43.41 (5.77)

APPENDIX X STATEMENTS OF CONTRIBUTION TO PUBLISHED ARTICLES

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Margaretha (Margo) van den Berg

Name/Title of Principal Supervisor: Associate Professor Leigh Signal

Name of Published Research Output and full reference:

van den Berg, M. J., Signal, T. L., Mulrine, H. M., Smith, A. A. T., Gander, P. H., & Serfontein, W. (2015). Monitoring and Managing Cabin Crew Sleep and Fatigue During an Ultra-Long Range Trip. Aerospace Medicine and Human Performance, 86(8), 705-713. doi:10.3357/amhp.4268.2015

In which Chapter is the Published Work: Chapter 3

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate: 70%

  and / or

- Describe the contribution that the candidate has made to the Published Work:

  The candidate made a significant contribution to the study design and prepared all study materials. She was responsible for coordinating the data collection and database development, conducted all statistical analyses, and prepared the manuscript for publication, which was reviewed and approved by all authors.

Margo van den Berg
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Date: 2019.04.24 12:07:18 +12'00'

Candidate's Signature

24 April 2019

Date

Leigh Signal
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Principal Supervisor's signature

24 April 2019

Date

GRS Version 3– 16 September 2011

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GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS

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We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Margaretha (Margo) van den Berg

Name/Title of Principal Supervisor: Associate Professor Leigh Signal

Name of Published Research Output and full reference:

van den Berg, M., Signal T.L., & Gander, P.H. Perceived workload is associated with cabin crew fatigue on Ultra-long range flights. Accepted for publication in The International Journal of Aerospace Psychology, published by Taylor & Francis (16 March 2019).

In which Chapter is the Published Work: Chapter 4

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate: 90%

  and / or

- Describe the contribution that the candidate has made to the Published Work:

  The candidate planned and conducted all statistical analyses and prepared the manuscript for publication, which was reviewed and approved by all authors.

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Candidate's Signature

24 April 2019

Date

Leigh Signal — Digitally signed by Leigh Signal DN: cn=Leigh Signal, o=Massey University, ou=Sleep/Wake Research Centre, email=t.l.signal@massey.ac.nz, c=NZ Date: 2019.04.24 11:40:00 +12'00'

Principal Supervisor's signature

24 April 2019

Date

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GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Margaretha (Margo) van den Berg

Name/Title of Principal Supervisor: Associate Professor Leigh Signal

Name of Published Research Output and full reference:

van den Berg, M., Signal, T. L., & Gander, P. H. Fatigue risk management for cabin crew: the importance of company support and sufficient rest for work-life balance - A qualitative study. Accepted for publication in Industrial Health (4 April 2019).

In which Chapter is the Published Work: Chapter 5

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate: 70%

  and / or

- Describe the contribution that the candidate has made to the Published Work:

  The candidate made a significant contribution to the study design and prepared all study materials. She was responsible for the data collection, conducted the thematic analysis, and prepared the manuscript for publication, which was reviewed and approved by all authors.

Margo van den Berg — Digitally signed by Margo van den Berg
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24 April 2019

Date

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Principal Supervisor's signature

24 April 2019

Date

GRS Version 3– 16 September 2011

APPENDIX Y PUBLICATIONS AND PRESENTATIONS ARISING FROM THIS THESIS

van den Berg, M., Signal, T. L., & Gander, P. H. (2019). Perceived Workload is Associated with Cabin Crew Fatigue on Ultra-Long Range Flights. *The International Journal of Aerospace Psychology*. DOI: 10.1080/24721840.2019.1621177.

van den Berg, M. J., Signal, T. L., & Gander, P. H. (2019). Fatigue Risk Management for Cabin Crew: The Importance of Company Support and Sufficient Rest for Work-Life Balance – a Qualitative Study. *Industrial Health* (Advance Publication) DOI: https://doi.org/10.2486/indhealth.2018-0233.

van den Berg, M., Signal, T. L., & Gander, P. H. (2018). Cabin crews' views on managing fatigue and the importance of sufficient rest and company support: A qualitative study. *Journal of Sleep Research, 27*(S1), P074.

van den Berg, M., Signal, T. L., & Gander, P. H. (2018). *Cabin crew sleep and fatigue: A qualitative study* (Report). Massey University: Wellington, New Zealand.

van den Berg, M. (2016a, 5-6 April). *Fatigue Management Developments for Cabin Crew*. Presentation at the Symposium for Fatigue Management Approaches in Aviation, ICAO Headquarters, Montréal, Canada. Retrieved from https://www.icao.int/Meetings/fmas/Documents/Presentations/Margo%20VandenBerg_FM%20Developments%20for%20Cabin%20Crew.pdf

van den Berg, M. (2016b, 7-8 May). *Monitoring & Managing Cabin Crew Sleep and Fatigue during an Ultra-Long Range Trip*. Presentation at the Sleep in Aotearoa - Australasian Sleep Association, Wellington, New Zealand

van den Berg, M. J., Signal, T. L., & Gander, P. H. (2015). Greater subjective workload is associated with higher cabin crew fatigue on ULR flights. *Sleep, 38*(Suppl), A87.

van den Berg, M. J., Signal, T. L., Mulrine, H. M., Smith, A. A. T., Gander, P. H., & Serfontein, W. (2015). Monitoring and Managing Cabin Crew Sleep and Fatigue During an Ultra-Long Range Trip. *Aerospace Medicine and Human Performance, 86*(8), 705-713. doi:10.3357/amhp.4268.2015

van den Berg, M. (2014, 18 February) *Evaluation of the sleep and performance of South African Airways cabin crew on the Johannesburg-New York ultra-long range flight*. Presentation at South African Airways. Johannesburg, South Africa.

van den Berg, M. J., Signal, T. L., Mulrine, H. M., Smith, A. A. T., & Gander, P. H. (2014) *Evaluation of the sleep and performance of South African Airways cabin crew on the Johannesburg-New York ultra-long range flight* (Report). Massey University: Wellington, New Zealand.