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In-Flight Sleep as a Pilot Fatigue Mitigation on Long Range and Ultra-Long Range Flights

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ABSTRACT

Objectives: Long range flights operate around the clock with long duty periods for pilots. To mitigate the effects of fatigue, these flights are operated by augmented crews, providing each pilot with the opportunity for sleep in on-board rest facilities. This thesis used a mixed methods approach to investigate the use of in-flight sleep and the factors that influence it.

Methods: Retrospective survey data (291 pilots, five studies) were analysed to provide an overview of pilots' sleep at home and investigate potential relationships with in-flight sleep. A second project monitored the sleep, fatigue and performance of 35 pilots operating a B767 flight route between Atlanta and Lagos. These projects were supplemented by thematic analysis of pilots' logbook comments on in-flight sleep (N=123) and on the way they manage their fatigue (N=629).

Results: Pilots viewed in-flight sleep as an important fatigue management strategy and actigraphic sleep monitoring confirmed that the B767 pilots made good use of their in-flight breaks for obtaining sleep. Self-ratings of in-flight sleep quality reflected ratings at home, but were usually poorer. Pilots indicated that the type, location and design of rest facilities affected sleep quality and duration, and identified strategies for minimizing sleep disturbances and improving alertness. Comments indicated that prior knowledge of in-flight break allocations can influence the planning of pre-trip sleep, use of naps, and in-flight sleep. Actigraphic measures of sleep indicated that the B767 pilots obtained more sleep in the 24 hours prior to departure than during baseline days regardless of their subsequent pattern of in-flight breaks, but it is unclear when they were advised about their break pattern. Ratings of sleepiness and fatigue increased across the B767 flights, but

psychomotor vigilance task performance at the start of duty and at top of descent was not associated with prior wakefulness, prior sleep duration or in-flight sleep duration.

Conclusions: In-flight sleep is a well-utilized and effective fatigue mitigation strategy that may be supplemented by other strategies such as flight preparation techniques. To further reduce pilot fatigue risk on long range flights, additional research is warranted into the effects of flight preparation techniques and in-flight break patterns.

(350 words)

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ABBREVIATIONS AND TECHNICAL TERMS

actigraphy	method of monitoring rest/activity rhythms over a period of days or weeks using a wrist worn device containing an accelerometer
AIC	Aike's Information Criterion
ANCOVA	analysis of covariance
ANOVA	analysis of variance
ANTE(1)	first-order ante-dependence
AR(1)	first-order auto-regressive
ATL	Atlanta, USA
augmented flight crew	a flight crew that comprises more than the minimum number required to operate the aeroplane and in which each flight crew member can leave his or her assigned post and be replaced by another appropriately qualified flight crew member for the purpose of in-flight rest (definition from ICAO, 2010, Attachment 4, section 4.2.1)
AW-64	model of actigraphy device
awakenings	term used in reference to recalled periods of wakefulness during the sleep period
baseline	24 hour period (beginning at 1600 UTC) that is free of duty and does not overlap with the last 24 hours prior to duty or the first 24 hours after duty
BIC	Bayesian Information Criterion
blocks off	moment when the aircraft first moves out of the gate at the start of the flight
blocks on	time at the end of the flight when the aircraft finally comes to rest at the gate
c-statistic	also termed concordance index, is a measure used to compare the goodness of fit of logistic regression models. It is a measure of the probability that the prediction of the outcome is better than chance

alone. A value of 0.5 indicates that the model prediction is no better than chance while a value of 1 indicates the model prediction is correct 100% of the time. Typically values above 0.7 are interpreted as the model being a reasonable fit while values above 0.8 indicate a strong model. (definition derived from documentation available in University of Manitoba, 2011)

CAAS	Civil Aviation Authority of Singapore
class 1	type of on-board rest facility; bunk or other lie-flat sleeping surface in an area separate from the flight deck and passenger cabin, where pilots can control a number of environmental factors (definition from Federal Aviation Administration, 2012b)
class 2	type of on-board rest facility; seat (in passenger cabin) that reclines to a flat or near-flat position and is separated from passengers by at least a curtain (definition from Federal Aviation Administration, 2012b)
class 3	type of on-board rest facility; seat (on flight deck or in passenger cabin) that reclines at least 40° providing leg and foot support (definition from Federal Aviation Administration, 2012b)
crew rest seat	refers to a class 2 or 3 facility located in the passenger cabin
cruise	low workload phase of flight between TOC and TOD during which pilots may have to opportunity for in-flight sleep
CS	compound symmetry
dB(A)	unit of measure of the loudness of sounds (decibels) adjusted for the way sounds are perceived by the human ear
domicile time	refers to time (in terms of time zone) at pilot's home base (i.e., departure airport of the outbound flight)
duty end	time when a pilot signs off duty after a flight (typically 1 hour after arrival)
duty start	time when a pilot reports for duty (signs on) prior to a flight (typically 2 hours prior to an international departure)
EEG	electroencephalography
EDT	Eastern Daylight Time
EMG	electromyogram

EOG	electrooculogram
EST	Eastern Standard Time
FAA	US Federal Aviation Administration
fatigue mitigation	a strategy, attitude or action used to minimise the effects of fatigue and/or the likelihood of fatigue occurring (also termed ‘fatigue mitigation strategy’ or ‘mitigation’)
FDP	flight duty period
flight segment	term used to refer to a single flight (i.e., flight without stopovers) between two points
flying crew	refers to the two pilots flying the aircraft during take-off and landing in an augmented crew
FRM	fatigue risk management
FRMS	fatigue risk management system
hypnogram	graphical representation of sleep architecture derived from the sleep stages identified from a polysomnographic recording
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFALPA	International Federation of Airline Pilots’ Associations
IGT	Iowa Gambling Task
JFK	New York city, USA
JNB	Johannesburg, South Africa
KSS	Karolinska Sleepiness Scale
landing	high-workload phase of flight between TOD and blocks on
landing crew	refers to the two pilots flying the aircraft during landing in an augmented crew
lapse	lapse in attention (typically a reaction time longer than 500ms)
LAX	Los Angeles, USA
LOS	Lagos, Nigeria

LR	long-range flight
mitigation	see <i>'fatigue mitigation'</i>
N1	NREM stage 1 sleep; stage 1 sleep
N2	NREM stage 2 sleep; stage 2 sleep
N3	NREM stage 3 sleep; also termed slow wave sleep
NIH	US National Institutes of Health
NREM	non-rapid eye movement sleep
OR	odds ratio
PAX	passengers
PF	pilot flying
PM	pilot monitoring
polysomnography	method of monitoring sleep using physiological measures; typically conducted in in a laboratory setting
post break 1	end of pilots' first in-flight rest period; time at which PVT test and post-sleep subjective ratings are completed
post break 2	end of pilots' second in-flight rest period; time at which PVT test and post-sleep subjective ratings are completed
post-flight	phase of flight between blocks on and duty end
pre-break 1	start of pilots' first in-flight rest period; time at which pre-sleep subjective ratings are completed
pre-break 2	start of pilots' first in-flight rest period; time at which pre-sleep subjective ratings are completed
pre-flight	phase of flight between duty start and blocks off
prospective	term used in reference to research designed to investigate situations and experiences occurring at the time of the study (e.g., in this thesis the data from the duty/sleep diary is prospective as participants are asked to record events of the study as they occur)
PSG	polysomnography
PVT	psychomotor vigilance task

relief crew	refers to the two additional pilots in a 4-person augmented crew
relief pilot	refers to the additional (third) pilot in a 3-person crew
REM	rapid eye movement sleep
rest break	refers to the in-flight rest opportunities of augmented crews
rest break pattern	refers to the specific rest breaks (1 st break, 2 nd break, 3 rd break,...) taken on a given flight
rest period	refers to a pilot's in-flight sleep opportunity (i.e., rest period 1 or 2)
rest facility	facility on-board the aircraft provided for augmented crews to use during their rest breaks
retrospective	term used in reference to research designed to investigate situations and experiences that occurred prior to the study (e.g., in this thesis the survey data is retrospective as it requires participants to reflect on their past experiences of in-flight sleep)
RT	reaction time
SCN	suprachiasmatic nuclei
SD	standard deviation
SE	sleep efficiency
SIN	Singapore, Singapore
SOL	sleep onset latency
SP	Samn-Perelli Crew Status Check
SPI	safety performance indicator
SWS	slow wave sleep
take-off	high workload phase of flight between blocks off and TOC
TIFST	total in-flight sleep time
TOC	top of climb
TOD	top of descent
TOL	tolerance statistics

TST	total sleep time
ULR	ultra-long range; flight with a planned duration of more than 16 hours (definition from Flight Safety Foundation, 2003a)
UTC	Coordinated Universal Time; common time standard used around the world to keep the time scales of the world's timing centres synchronised (definition from www.timeanddate.com)
VIF	variance inflation factor
wake maintenance zone	period in the early evening during which wake drive is high and it is difficult to initiate sleep; performance during this period it typically maintained
WAT	West Africa Time Zone
window of circadian low	WOCL, period in the early morning during which sleep drive and sleepiness are high and performance is lower is impaired; fatigue-related errors are more likely during this time
WOCL	window of circadian low

*Il est peu et de réussites faciles,
et d'échecs définitifs.*

~Marcel Proust

