THE IMPACT OF LAYOVER LENGTH ON THE FATIGUE AND RECOVERY OF LONG-HAUL FLIGHT CREW

Nicole Lamond, Renee Petrilli, Drew Dawson, Gregory D. Roach
The Centre for Sleep Research
The University of South Australia
Adelaide, Australia
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INTRODUCTION

Until recently, research into fatigue in commercial long-haul flight operations in Australia has been lacking. This has meant that the prescriptive rules that Australian airlines have traditionally employed to manage flight operations, which relate to maximum flight and duty limits and minimum rest requirements, are not based on scientific evidence. As a consequence, it is possible that the flight operations currently worked by Australian long-haul pilots produce problematic levels of fatigue. This raises serious concerns about flight safety, given that fatigue has been reported as a contributing factor to operational errors by flight crew, and has contributed to several near-misses, incidents, and fatal accidents in civil aviation (1-4).

In recognition of the need for systematic research, a series of studies to assess the sleep behaviour and fatigue levels of commercial long-haul pilots were recently conducted by our laboratory, in collaboration with Qantas Airways Ltd, the Civil Aviation Safety Authority (CASA), the Australian and International Pilots Association (AIPA). One particular question that this research was designed to answer was whether layover length has an impact on pilots’ fatigue during flight operations and in turn, during the recovery period immediately following their pattern.

A major contributor to pilot fatigue during long-haul operations is the sleep disruption associated with transmeridian flight (5-6). The inability of the circadian timing system to instantly re-adjust to the rapid phase shift in time cues that occurs when several time zones are crossed (7) can directly impact on sleep/wake behaviour. Specifically, pilots may experience difficulty initiating or maintaining sleep during their layover, which may in turn, cause increased fatigue, decreased alertness and impaired performance (8-11). Anecdotal reports from Australian flight crew suggest that layover length is an important determinant of how fatiguing the flight pattern is. As the levels of fatigue experienced during flight operations are likely to affect the amount of sleep that flight crew require to adequately recover following their trip, layover length may also be an important determinant of the amount of time that flight crew should have off prior to subsequent duty periods.

Discussion with Australian flight crew indicates that several prefer a longer layover as it provides increased opportunity to obtain adequate sleep to recover. Indeed, many flight crew have suggested that relatively quick turn-around times lead to elevated levels of fatigue as they
restrict the opportunity to obtain sufficient sleep. Conversely, several flight crew have indicated a preference for a relatively short layover, during which they often choose to maintain a sleep/wake schedule that is aligned with their home time zone, rather than attempting to adjust to the new time zone for several days. As this means that their sleep/wake cycle is not desynchronized when they arrive home after the trip, they feel their sleep is less disturbed, thereby facilitating recovery from the flight operations.

The aim of the current study was to investigate the impact of layover length on the fatigue levels of flight crew during (1) long-haul flight operations, and (2) the recovery period immediately following long-haul flight operations.
METHODS

Participants

Nineteen experienced male pilots (10 Captains, 9 First Officers), aged 34 to 57 years (mean age = 46.7±6.8 years), participated in the current study. They averaged 12,343 total flight hours (4,900 to 16,399), with 2373 flying hours (290 to 8000) in Boeing 747-400 aircraft. All had been operating aircraft for over 10 years (mean = 29.8±8.6 years).

Methodology

Flight Operations

Throughout the study, pilots kept a record of their flight/duty times. For each flight sector, they were asked to record the (1) date and time that the duty period began, (2) IATA code of the departure port and the arrival port, and (3) departure and arrival time for each flight sector.

These records indicated that outbound flight to Los Angeles (LAX) departed from the East Coast of Australia (AUS), from Sydney (47%), Melbourne (32%) or Brisbane (21%). The flight departed AUS between 0900hr and 1330hr local time, and arrived in LAX between 0630hr and 1030hr local time. The duration of the sector was between 12.6 and 14.6 hours (mean duration = 13.5±0.6 hours). The inbound return flight from LAX to the East Coast of Australia (Sydney 58%, Melbourne 32%, or Brisbane 10%) was between 13.4 and 15.5 hours (mean duration = 14.3±0.6 hours). The flight departed LAX between 2030hr and 2300hr local time, and arrived in AUS between 0630hr and 0930hr local time. The duration of the layover in LAX was classified as either short (n=9, mean±stdev = 39±0.8hrs) or long (n=10, mean±stdev = 62.2±0.9hrs).

Subjective Fatigue

Subjective fatigue was assessed using the Samn-Perelli Fatigue Checklist (12), a 7-point scale where 1 = ‘Fully alert, wide awake’, and 7 = ‘Completely exhausted, unable to function effectively’. Flight crew were asked to provide a subjective rating of their fatigue level just after they boarded the aircraft, and just before they walked off the aircraft. In addition, they recorded
their fatigue level during the four days immediately following the flight pattern (commencing the day after their first night at home), prior to completing their Palm-PVT (see below).

**Objective Fatigue: Palm-PVT**

A 5-minute visual psychomotor vigilance task (PVT) was used to objectively evaluate fatigue. Throughout the study, flight crew carried a PalmPilot - a small, compact, hand-held electronic device. In the current study, the Zirc71™ handheld (PalmOne Inc., United States) was used. The PalmPilot contained a version of the PVT program (Palm-PVT) that was recently developed by Walter Reed Army Institute, and subsequently validated as a reliable assay of fatigue in two independent studies (13-14).

Flight crew were sent the PalmPilot prior to the commencement of the flight pattern, and instructed to complete three practice Palm-PVTs, to ensure that were familiar with the device and to minimize improvements in performance resulting from learning. Throughout flight operations, they were instructed to complete a Palm-PVT (i) as soon as possible after the top of climb, and (ii) as close as possible to the top of descent. Flight crew were told that operational requirements always took precedence over completing a task. If they had to miss or interrupt a test, they were instructed to complete another Palm-PVT at the next available opportunity. Flight crew were also asked to complete a Palm-PVT at (or as close as possible to) 1000hr, 1330hr, and 1700hr (local time) each day, for four days after the flight pattern. The average of the three tests was then calculated.

The Palm-PVT required the participants to attend to a display for the duration of the test. A visual stimulus (black bull’s-eye) appeared on the screen every 2-10 seconds (this interstimulus interval was random). As quickly as possible after the appearance of the stimulus, participants pressed the appropriate response key with the thumb of their dominant hand. Participants were instructed to avoid trying to anticipate the stimulus. Their response time, in 100ths of a second, was then briefly displayed before the next stimulus was presented.

**Statistical Analyses**

For this report, one PVT metric was evaluated - increases in response times (RT). As RT data often have a proportionality between the mean and SD, a reciprocal transformation was applied to the raw data before analysis. This transformation has the effect of substantially
decreasing the contribution of very long lapses, and emphasizing slowing in the optimum and intermediate range of responses (15).

Evaluation of systematic changes in subjective fatigue and RTs before/after each flight sector and in the four days immediately after the flight pattern were assessed separately for short and long layovers, using repeated-measures analysis of variance (ANOVA). Where necessary, the Greenhouse-Geisser procedure was applied to produce more conservative degrees of freedom for all ANOVA analyses. Missing values were replaced by the group mean. Planned comparisons were used to determine at which points during flights operations and the recovery phase fatigue significantly differed from pre-trip levels.
RESULTS

Subjective Fatigue

Analysis indicated that for flight crew with a long layover, subjective fatigue significantly varied across the experimental period ($F_{7,63}=16.4$, $p<0.0001$). As shown in Figure 1, planned comparisons indicated that relative to pre-flight ratings, subjective fatigue at the end of each flight sector was significantly elevated. Subjective fatigue had returned to pre-trip levels following the first recovery night at home. Similarly, for flight crew with a short layover, analysis indicated that subjective fatigue significantly varied across the experimental period ($F_{7,56}=16.4$, $p<0.0001$). Notably, fatigue was significantly higher than pre-trip ratings at the end of each flight sector and for all of the recovery days following the flight operation.

![Figure 1](image-url)

**Figure 1.** Subjective fatigue at the start and end of the outbound (AUS-LAX) and inbound (LAX-AUS) flight, and during the four recovery days immediately following the pattern. Ratings significantly different from pre-trip are indicated with a † for long layovers and a * for short layovers.
Reaction Time Performance (1/RT)

For flight crew with a long layover, RTs significantly varied across the experimental period (F_{7,63}=3.6, p<0.019). Planned comparisons indicated that relative to pre-trip, RTs were significantly faster at the beginning of the inbound flight. As can be seen in Figure 2, RTs were slower at the end of the outbound flight, compared to pre-trip, however the difference was not statistically significant (p=0.073).

Analysis indicated that RTs significantly varied across the pattern for flight crew with a short layover (F_{7,56}=4.0, p<0.001). Relative to pre-trip, RTs were significantly slower at the end of both the outbound and outbound flight, and at the start of the inbound flight (i.e. following the layover). RTs were also significantly slower than pre-trip on recovery day 2 and 3.

Figure 2. Palm-PVT reaction times (1/RT) at the start and end of the outbound (AUS-LAX) and inbound (LAX-AUS) flight, and during the four recovery days immediately following the pattern. Ratings significantly different from pre-trip are indicated with a † for long layovers and a * for short layovers.
DISCUSSION

Anecdotal reports from long-haul flight crew in Australia suggest that the duration of their layover can have a significant impact on the levels of fatigue that they experience during and following flight operations. While several have suggested that quick turn-around times lead to greater levels of fatigue, as they restrict the opportunity to obtain sufficient sleep to reverse the effects of fatigue, others prefer short layovers as they can maintain a sleep/wake schedule that is aligned with their home time zone, thereby reducing sleep disruption during the recovery period following the pattern. Importantly, due to a lack of research into fatigue in long-haul flight operations in Australia, scientific evidence to support either suggestion has not been available. The current study systematically assessed the levels of fatigue experienced during long-haul flight operations from Australia, with either a short or longer layover in the United States (US).

Several long-haul flights depart from Australia to the US each day. While the individual flight sectors are of roughly equivalent duration, and often timing, the duration of the overall pattern may vary depending on the length of time the pilots are required to remain in the US before returning home. In the current study, two common layover lengths were examined: relatively short (<40 hours) and longer layovers (2-3 days). As is typical of long-haul flight from AUS to the US, both the outbound and inbound sector were >12 hours in duration. While rest facilities are provided for flight crew, in many cases only a small amount of sleep is obtained (e.g. see proceedings paper by Sletten, Roach, Darwent and Dawson). It is therefore not surprising that flight crew felt fatigued at the end of each flight sector than they did prior to departing. As can be seen in Figure 1, flight crew typically reported feeling “moderately tired, let down” or “extremely tired, very difficult to concentrate” at the end of the outbound flight. At the end of the inbound flight, ratings were slightly lower, with most indicating they felt “moderately tired, let down” or “a little tried, less than fresh”. Notably, from a subjective point of view, flight crew did not appear to feel that either layover length was more fatiguing than the other during flight operations.

Interestingly, the objective data suggests that layover length did significantly impact on flight crew fatigue. As shown in Figure 2, for both layover lengths, flight crews’ reports of elevated levels of fatigue at the end of the outbound sector were concomitant with slower response times. Notably however, despite comparable subjective ratings, response times at the
beginning of the inbound flight differed as a function of layover length. Flight crew who had a short layover demonstrated significantly lower response times at the end of the layover period. This data suggests that the shorter layover did not provide flight crew with sufficient opportunity to adequately recover. As a result, they were also more fatigued, and responding more slowly at the end of the flight pattern than those with the longer layover.

It is apparent that inadequate recovery opportunity during flight operations also had a significant impact on the flight crews’ recovery following the flight pattern. Even after four recovery nights at home, flight crew with a short layover did not completely recover from the flight operation. Subjectively, flight crew who had the short layover felt more fatigued than they did prior to the pattern for fours days after returning home. In line with this, response times remained significantly below pre-trip levels until the fourth recovery day at home. Notably, response times on the fourth recovery were also still slower than pre-trip, however due to a small number of observations (and lack of power), the difference was no longer statistically significant.

In contrast, at the end of the layover period, prior to the inbound flight, those with a longer layover actually had faster response times than they demonstrated prior to the pattern, suggesting 2-3 days was enough time for them to obtain adequate restorative sleep. Presumably due to the fact they were not as fatigued at the end of the flight pattern as those with a short layover, those with the longer layover indicated that they felt restored to pre-trip levels after just one night-time sleep period. In line with this, their response times were also comparable to pre-trip after only one recovery night.

The findings from the current study suggest that long-haul flight crew accumulate higher levels of fatigue when layover length is short (<40 hour), compared to flight operations with a longer layover. Due to higher levels of fatigue during flight operations, shorter layovers also significantly impact on the amount of time required to recover after the pattern. While flight crew with a longer layover recover following one recovery night, those with a short layover appear to need at least three or four nights. Notably, response times on the Palm-PVT were used as an objective assay of fatigue in the current study. While it was clear that flight crew experienced elevated levels of fatigue, particularly those with a short layover, how this impacts on operational performance is not currently known. Studies that are more operationally realistic, such as the simulator studies we are currently conducting, would be better suited to answering this question.
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REFERENCES


