Do Short International Layovers Allow Sufficient Opportunity for Pilots to Recover?

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DO SHORT INTERNATIONAL LAYOVERS ALLOW SUFFICIENT OPPORTUNITY FOR PILOTS TO RECOVER?

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For Australian pilots, short layovers (<40 h) are a feature of many international patterns. However, anecdotal reports suggest that flight crew members find patterns with short slips more fatiguing than those with a longer international layover, as they restrict the opportunity to obtain sufficient sleep. The current study aimed to determine whether pilots operating international patterns with short layovers have sufficient opportunity to recover prior to the inbound flight. Nineteen international pilots (ten captains, nine first officers) operating a direct return pattern from Australia to Los Angeles (LAX) with a short \( (n=9) \) 9 ± 0.8 h (mean ± S.D) or long \( (n=10) \) 62.2 ± 0.9 h LAX layover wore an activity monitor and kept a sleep/duty diary during the pattern. Immediately before and after each flight, pilots completed a 5 min PalmPilot-based psychomotor vigilance task (Palm-PVT). Flights were of comparable duration outbound \( (3.5 ± 0.6 \text{ h}) \) and inbound \( (14.3 ± 0.6 \text{ h}) \) and timing.

The amount of sleep obtained in-flight did not significantly vary as a function of layover length. However, pilots obtained significantly more sleep during the inbound \( (3.7 ± 0.8 \text{ h}) \) than the outbound flight \( (2.2 ± 0.8 \text{ h}) \). Pilots with the shorter layover obtained significantly less sleep in total during layover \( (14.0 ± 2.7 \text{ h} \text{ vs.} 19.6 ± 2.5 \text{ h}) \), due to significantly fewer sleep periods \( (3.0 ± 0.7 \text{ vs.} 4.0 ± 0.9 \text{ h}) \). However, neither mean sleep duration nor the sleep obtained in the 24 h prior to the inbound flight significantly differed as a function of layover length. Response speed significantly varied across the pattern, and a significant interaction was also observed. For pilots with a short layover, response speed was significantly slower at the end of both the outbound and inbound flight, and prior to the inbound flight (i.e., at the end of layover), relative to response speed at the start of the pattern (pre-trip). Similarly, response speed for the longer layover was slower at the end of the outbound flight compared to pre-trip (approaching significance, \( p = 0.073 \)). However, response speed at the beginning of the inbound flight was significantly faster than pre-trip and did not significantly differ from pre-trip at the end of the inbound flight. The data suggest that short slips (<40 h) do not allow pilots the opportunity to obtain sufficient sleep to reverse the effects of fatigue accumulated during the
outbound flight. As a result, their response speed prior to the inbound flight is substantially slower than the response speed of flight crew with a longer layover.

**Keywords** International flight operations, Layover length, Sleep, Fatigue, Psychomotor vigilance, Airline pilots

**INTRODUCTION**

Fatigue has been reported to be a contributing factor to operational errors by the flight crew and has contributed to several near-misses, incidents, and fatal accidents in civil aviation (Cabon et al., 2000, Coleman and Dement, 1986, Green, 1985, Lyman and Orlady, 1980). A major cause of pilot fatigue during long-haul flight operations is sleep disruption, particularly insufficient sleep during the layover (Gander et al., 1998; Sasaki et al., 1993). Flight crew often experience difficulty initiating or maintaining sleep during layover as the circadian timing system is unable to instantly re-adjust to the rapid phase shift in time cues that occurs during transmeridian flight (Nicholson et al., 1986; Sasaki et al., 1986; Wever, 1980). As a consequence, cumulative sleep loss, increased fatigue, and impaired performance are observed (Klein and Wegmann, 1980; Wegmann and Klein, 1985; Wright et al., 1983). Thus, obtaining adequate sleep during layover is critical to the success of international flight operations.

Reports from Australian flight crew suggest that layover duration is an important determinant of the level of fatigue experienced during international flight operations. Specifically, it has been suggested that the opportunity for sleep associated with quick turnaround times is insufficient, resulting in elevated levels of fatigue (Samel et al., 1991). Thus, many pilots prefer a longer layover as it provides increased opportunity to obtain adequate sleep and recover prior to the homebound flight. However, instead of adapting their sleep/wake behavior to the new time zone, some flight crews choose to maintain a sleep/wake schedule that is aligned with their home time zone, in an attempt to reduce the sleep disruption that typically occurs after their return home (Sasaki et al., 1993; Wegmann et al., 1986). For pilots who adopt this sleep strategy, short layovers that involve less time away from home are preferable.

Several long-haul flights destined for Los Angeles depart from the east coast of Australia each day. While the individual flight sectors are of roughly equivalent duration and the timing of the flights are often similar, the duration of the overall pattern may vary depending on the length of time the pilots are required to remain in the United States before returning home. Until recently, however, research regarding the sleep and fatigue of Australian pilots during international flight operations has been lacking. Thus, it is possible that the flight operations currently
worked by Australian long-haul flight crew produce problematic levels of fatigue.

A recognition of the need for systematic research in this area prompted the present research group, in collaboration with Qantas Airways Ltd, the Civil Aviation Safety Authority, and the Australian and International Pilots Association, to conduct a series of studies to assess the sleep behavior and fatigue levels of commercial long-haul pilots. The aim of the current study was to systematically assess the levels of fatigue experienced during long-haul flight operations from Australia, with either a short (<40 h) or longer (2–3 day) layover in the United States.

METHODS

Participants

Nineteen experienced male pilots (ten captains, nine first officers), aged 35–59 years (mean and S.D.: 50.8 ± 6.7 years), participated in the current study. They averaged 14,732 ± 5,322.5 total flight hours (range: 6,167–23,679), and each had been operating aircraft for more than ten years (29.8 ± 8.6 years). Prior to participation, all pilots provided written consent and confirmed their volunteer status. Each was assigned a unique identification code to ensure anonymity. Participants did not receive any additional payment for participating in the study above their usual salary. There was no medical selection criterion for participation in this study, as Qantas pilots are required to pass regular medical checks. The study was approved by the University of South Australia Human Research Ethics Committee, using guidelines established by the National Health and Medical Research Council of Australia, and the research methods conformed to the journal standards of good practice (Touitou et al., 2004).

Procedure

Data were collected while the flight crew was operating a direct return pattern from Australia to Los Angeles (LAX). On each occasion, data were collected from both the captain and first officer operating the pattern. The flight patterns targeted had flight sectors that were of similar timing, but involved different length LAX layovers. Specifically, crews had either a short layover in LAX (n = 9), on average 39 ± 0.8 h, or longer layover in LAX (n = 10), on average 62.2 ± 0.9 h. Prior to the international pattern, each participant had at least four consecutive non-flying days.

During the pattern (in-flight and layover), the flight crew provided detailed information about their sleep patterns and flight/duty times. For each sleep period, including in-flight sleep, pilots recorded the
location of the sleep period, the time of sleep onset, and the final wake
time. For each flight sector, pilots recorded the date and time that the
duty period began, the IATA code of the departure and arrival ports,
and the departure and arrival times for each flight sector.

Objective assessments of sleep/wake were made using activity monitors
(Mini Mitter, Bend, Oregon, USA) and Actiware-sleep software (Cam-
bridge Neurotechnology Ltd., Cambridge, UK). Each activity monitor
contained a piezo-electric accelerometer with a sensitivity of 0.1 g. The
analog sensor sampled movement every 125 min and the information
was stored in one-minute intervals for analysis. Pilots were required to
wear the activity monitor on their wrist for the duration of the study.

A 5 min visual psychomotor vigilance task (PVT), which has been
widely used in studies of sleep deprivation, shift work, and fatigue (e.g.,
Dorrian et al., 2005), was used to objectively evaluate fatigue at the begin-
ning and end of each flight sector. Throughout the study, the flight crew
carried a PalmPilot that contained a validated version of the PVT
program (Palm-PVT) specifically developed by the Walter Reed Army
Institute for use in the field (Lamond et al., 2005; Thorne et al., 1985,
2005). For each trial, pilots were required to attend to the display on the
hand-held device and press the response button as quickly as possible
after the appearance of the visual stimulus (a black bull's-eye), which had
a random inter-stimulus interval of 2–10 sec. As the PVT is reported to
have a learning curve of 1–3 trials (Dinges et al., 1997), the Palm-PVT
was sent to the flight crew prior to the commencement of the flight
pattern, and they were instructed to complete three practice tests.

**Statistical Analysis**

The duration of each sleep period was calculated using the activity
monitoring data in conjunction with sleep diaries. For this report, an
increase in Palm-PVT response speed was used as a measure indicative
of increased fatigue. As response speed data often has a proportionality
between the mean and SD, a reciprocal transformation was applied to
the raw data before analysis. For each variable, missing values were
replaced by the group mean.

Statistical analysis was performed with SPSS (version 11.0.2, SPSS Inc,
Chicago, Illinois, USA). The amount of sleep obtained in-flight and Palm-
PVT response speed were analyzed using separate repeated measures
ANOVA, with one between (layover length) and one within (test time)
subject factor. In accordance with standard procedures (Kirk, 1995),
simple main effects analyses were applied to all significant layover
length-test time interactions (i.e., simple main effects of test time for
each layover length), and where relevant, planned comparisons were per-
formed to specify differences among mean values. Independent sample
t-tests were used to assess differences in sleep during the LAX layover as a function of layover length.

RESULTS

Flight Operations

The outbound flight to Los Angeles (duration: $13.5 \pm 0.6$ h) departed the East Coast of Australia between 09:00 and 13:30 h local time, and arrived in LAX between 06:30 h and 10:30 h local time. The inbound return flight (duration: $14.3 \pm 0.6$ h) departed LAX between 20:30 h and 23:00 h local time, and arrived in AUS between 06:30 h and 09:30 h local time. Flight duration did not significantly vary as a function of layover length.

Sleep

The amount of sleep obtained in-flight did not significantly vary as a function of layover length. However, for both the short and longer layover, pilots obtained significantly $(F_{1,17} = 26.6, p = 0.0001)$ more sleep during the inbound flight ($3.7 \pm 0.8$ h) than they did during the outbound flight ($2.2 \pm 0.8$ h). Pilots with the shorter layover obtained significantly $(t_{4.8} = 17, p = 0.0001)$ less sleep in total during layover ($14.0 \pm 2.7$ vs. $19.6 \pm 2.5$ h), due to significantly $(t_{2.6} = 17, p = 0.0001)$ fewer sleep periods ($3.0 \pm 0.7$ vs. $4.0 \pm 0.9$). However, neither the mean duration of each sleep period nor the sleep obtained in the 24 h prior to the inbound flight significantly differed as a function of layover length (see Figure 1).

Response Speed

Figure 2 displays the mean Palm-PVT response speed ([1/mean response time (RT)] $\times 1000$) as a function of layover length and test time (pre- and post-flight). Response speed varied significantly across the pattern $(F_{3,51} = 6.9, p = 0.001)$, but overall it did not significantly vary as a function of layover length $(F_{1,17} = 3.7, p = 0.073)$. A significant layover length $\times$ test time interaction was found $(F_{3,51} = 4.3, p = 0.009)$, indicating that the impact of the flight pattern on response speed was different for the short and longer layover. Analysis of the simple main effects confirmed that response speed significantly varied across the pattern for both the short $(F_{3,24} = 5.8, p = 0.004)$ and longer $(F_{3,27} = 5.4, p = 0.005)$ layover. Planned comparisons indicated that relative to the start of the pattern, before pilots left Australia (i.e., pre-trip), response speed for pilots with a short layover was significantly slower at
the end of both the outbound and inbound flight and prior to the inbound flight (i.e., at the end of layover). As can be seen in Figure 2, the response speed for the longer layover was slower at the end of the outbound flight compared to pre-trip (before leaving Australia); however, planned comparisons indicated that the difference was not statistically significant ($p = 0.073$). The response speed at the beginning of the inbound flight was significantly faster than response speed in Australia prior to the trip and did not significantly differ from the pre-trip level at the end of the inbound flight.

**DISCUSSION**

Until recently, scientific evidence regarding the impact of layover length on the sleep and fatigue of Australian pilots during international flight operations has not been available. Thus, the aim of the current study was to systematically assess the sleep and levels of fatigue associated with long-haul flight operations from Australia to the United States with either a short or longer international layover. As is typical of long-haul flight operations, the outbound sector (AUS-LAX) involved long duty hours and rapid multiple time zone changes. These conditions are typically associated with sleep disruption and circadian desynchronization (Sasaki et al., 1993; Wegmann et al., 1986), and despite onboard rest facilities, the flight crew obtained only a small amount of sleep in-flight. Thus, it is

![FIGURE 1](image-url) The amount of sleep obtained during each layover sleep period (left) and in the 24 h prior to the inbound (LAX-AUS) flight, for a flight crew with a short (grey) and longer (black) LAX layover.
not surprising that the flight crew was significantly more fatigued, as indicated by slower response speed, at the end of the flight than they were prior to departing Australia.

It is apparent that these problems were exacerbated when the international layover was relatively short. Flight crews who had a short layover demonstrated significant levels of fatigue at the end of the layover period, with no apparent recovery from the outbound flight. In contrast, at the end of the layover period and prior to the inbound flight, those with a longer layover appeared to be less fatigued than they were prior to the pattern. As the layover did not appear to provide the flight crew with sufficient opportunity to completely recover, the flight crew who had a short layover were also responding more slowly at the end of the pattern (following the inbound flight) than those with the longer layover, indicating higher levels of fatigue. Indeed, the response speed at the start and end of the pattern did not differ for the flight crew with the longer LAX layover.

One of the major determinants of an individual’s level of fatigue at any point in time is their recent sleep history (Dawson and McCulloch, 2005). In general, the length of the layover did not appear to have an impact on the average amount of sleep pilots obtained during each sleep period while in LAX. Moreover, although not statistically significant, pilots with the
short layover obtained more sleep in the 24 h immediately prior to the inbound flight than did those with the longer layover (9.0 ± 2.0 vs. 7.8 ± 1.9 h). Presumably this was because they knew they had less opportunity (i.e., a fewer number of days) to obtain sufficient recuperative sleep and thus ensured they had more sleep periods per day to increase the total amount of sleep obtained. Yet, despite the fact that they obtained more sleep prior to the inbound flight, the response speed of the pilots on the Palm-PVT was significantly slower than it was with the longer layover. Moreover, they had not recovered from the outbound flight. This suggests that the flight crew was unable to reverse the effects of fatigue accumulated during the outbound flight when they were provided with only one full nighttime sleep period. That is, the number of recovery nights associated with the short layover did not provide the flight crew with sufficient opportunity to recover.

This is not altogether surprising given that the average length of each sleep period was just under 5 h. Thus, while the flight crew typically obtained 7-9 h sleep in the 24 h period prior to the inbound flight, which in and of itself may not be enough to ensure adequate recovery from an international flight, the sleep was obtained during several sleep periods, rather than a single one. Research suggests that in addition to total sleep time, the continuity of sleep is a primary predictor of the restorative value of a sleep period (Wesensten et al., 1999). Typically, split sleep periods are not as restorative as a single continuous period. Furthermore, that the flight crew was not sleeping at home and was likely sleeping at biologically inappropriate times of the day due to circadian desynchronization suggests that the quality of the sleep may have been degraded, and the sleep less restorative than usual. In contrast, it is apparent that the longer layover provided flight crew with opportunity (i.e., at least two full nights) to obtain adequate restorative sleep to reverse the effects of fatigue. Moreover, the fact that the response speed of the pilots at the end of the layover was faster than it was pre-trip suggests they were more rested at the end of layover than prior to the trip.

As a final note, it is interesting that pilots obtained significantly more sleep during the inbound than outbound (mean difference: 1.5 h) flight, independent of layover length, even though the sector was only slightly longer. A possible explanation for this is that due to a long flight, the circadian desynchronization and sleep disruption during layover left pilots more fatigued during the inbound flight compared to when they initially left Australia (i.e., after four days off at home). While this may have been the case for the pilots with a short layover, it is an unlikely explanation for those with a longer layover. Rather than demonstrate higher levels of fatigue, pilots with the longer layover had significantly faster response speed than they did prior to the trip, suggesting that they obtained sufficient sleep during layover to reverse the fatigue accumulated during the
outbound flight. Thus, the difference in in-flight sleep is likely due to other factors, in particular the timing of the flights. While the inbound flight departed late in the evening and flew through the night (the optimal time to obtain sleep), the outbound flight was during the day, when sleep is harder to obtain and pilots had been awake for less time prior to the flight.

Importantly, this study is not without its limitations, and thus the results should be interpreted with some caution. In particular, as with many time-intensive field studies, the sample size was relatively small, which may limit the generalization of the results. Notably, however, the repeated measures design increased the number of observations in total, particularly for the layover sleep and Palm-PVT data. Despite this, the small sample size is a likely explanation for why the decrease in response speed at the end of the outbound flight (longer layover) did not reach statistical significance. A further point relates to the use of the Palm-PVT response speed 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, the extent to which this affects operational performance is not currently known and cannot be determined from this study. Studies that are more operationally realistic, such as the simulator studies being currently conducted, would be better suited for answering this question.

CONCLUSION

The findings from the current study suggest that short (<40 h) international layovers during flight patterns from Australia to Los Angeles and back do not provide flight crew with sufficient opportunity to reverse the effects of fatigue on response speed that accumulate during the outbound flight. In contrast, international layovers involving at least two full nighttime sleep opportunities appear to provide sufficient opportunity for the flight crew to obtain adequate restorative sleep to reverse the effects of fatigue associated with international flight.

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