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Pros and Cons of Strategic Napping on Long Haul Flights

P.J.L. Valk & M. Simons

Netherlands Aerospace Medical Centre
P.O. Box 22, 3769 ZG Soesterberg, The Netherlands

SUMMARY

Long haul operations involve rapid multiple time zone changes and long, irregular work schedules. These factors can result in sleep loss, circadian disruption, and fatigue with consequent effects on pilot's performance and alertness. A controlled nap in the cockpit is considered to be a useful countermeasure to inflight fatigue. Therefore, a study was conducted on the effects of a 40-minutes controlled rest period on the flight deck on crew performance and alertness. The alertness of the designated waking pilot, who has to remain alert while his colleague is resting, was explicitly assessed. Data was collected of 59 pilots, flying North-Atlantic B747-300 trips as scheduled in their regular duty roster. Pilots were equipped with a palmtop computer and an actigraph for objective and subjective assessment of quantity and quality of cockpit naps, alertness, and performance on a vigilance dual-task. During flights, measurements were performed before and after the rest period and before top of descent. It was found that a cockpit rest period improved alertness and performance of the rested pilots up to top of descent. Sleep during the rest period provided more improvement than rest alone. A number of designated waking pilots had difficulties in maintaining a sufficient level of alertness during the rest period of their colleague pilot. It is recommended to implement the use of preplanned controlled rest periods on the flight deck as a preventive fatigue countermeasure in 2- and 3-person flight deck operations. Measures to safeguard the alertness of designated waking pilots and guidelines to secure flight safety are discussed.

INTRODUCTION

Long-haul flight operations are characterized by rapid multiple time zone changes, circadian disruptions, sleep disturbances and sleep loss. These factors may result in levels of fatigue, that have adverse effects on pilot performance and alertness with consequent reduction of safety and operational effectiveness. Therefore, pilot fatigue is a major safety concern. The US National Transportation Safety Board has recognized fatigue and sleepiness of pilots as a contributory factor in aircraft accidents (1). The aircraft cabin environment with lower pressure, low relative humidity, constant background noise, dim lighting, and a low workload during cruise-flight can contribute to the difficulty of remaining vigilant and awake (2).
One compensatory response to fatigue and sleepiness is the occurrence of unplanned and involuntary sleeping in the cockpit, especially during night flying (3,4,5). Involuntary sleeping in the cockpit might endanger flight safety. There is evidence, both from laboratory and field studies, that a preplanned and controlled rest period is a useful method to prevent inadvertent sleeping in the cockpit and to improve performance of fatigued pilots (5,6,7).
The Netherlands Aeronautical Inspectorate (RLD/LI) reserved approval of the controlled rest on the flight deck until the safety of this procedure has been adequately demonstrated. This waiting attitude was based on the arguments that thus far alertness and performance of the designated alert pilot (waking pilot) have not been explicitly assessed.

METHOD

Subjects

Participants of this study included 68 pilots (34 captains and 34 first officers) flying on Boeing 747-300 operations (67 male, 1 female), who were executing regular trips within their regular duty roster. Subjects participated on a voluntary basis and were not paid for their participation. Confidentiality and anonymity of subject's data were guaranteed. Data sets of 59 pilots (all male; 30 captains and 29 first officers) were available for analysis. Mean age was 38.2 years (range 23-57) and mean total flight hours logged was 7788 (range 2000-17.000). All subjects considered themselves to be good sleepers when at home.

Trip characteristics

Measurements were made on 3-days North Atlantic trips involving Boeing 747-300 operations with a 3-person cockpit crew (Cpt, FO, FE). Characteristics of the trips are presented in Table 1.All outbound flights were executed during daylight and all inbound flights during the night. The time difference between Amsterdam and Detroit, Toronto, Montreal was 6 hours. Time difference between Amsterdam and Chicago was 7 hours. Stopovers included a time period of 22-25 hours from the afternoon on the day of arrival till the afternoon or evening the next day.

Table 1. Trip characteristics. Flight times (flt) as scheduled by the airline. AMS=Amsterdam, DTW=Detroit, ORD=Chicago, YYZ=Toronto, YMX=Montreal.

outbound ✈	dep (local)	arr (local)	flt (hrs)
AMS-ORD	11:20	13:00	08:40
AMS-DTW	14:50	17:00	08:10
AMS-YYZ	14:45	16:40	07:55
AMS-YMX	15:25	16:45	07:20
inbound ✈	**dep (local)**	**arr (local)**	**flt (hrs)**
ORD-AMS	16:20	07:10	07:50
DTW-AMS	22:20	11:45	07:25
YYZ-AMS	18:40	07:45	07:05
YMX-AMS	18:35	07:00	06:25

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Cockpit rest guidelines
In order to guarantee safety of the flight operations, in this study the following rules were applied with respect to the controlled rest on the flight deck:

1. Controlled rest is only permitted during cruise-flight in a low workload phase of flight
2. The duration of the rest period will not exceed 40 minutes
3. Planning should take into account individual needs
4. When planning, existing CRM-principles have to be followed
5. Only one crewmember is permitted to rest at a time, while the other pilot (and FE) maintains flight operations
6. The designated waking pilot should be adequately briefed prior to the rest period of the designated resting pilot. Prior to resuming flight duties, the rested crewmember should be briefed
7. The flight deck alarm clock should be set to a period of maximal 40 minutes
8. All rest periods should be terminated at least 1 hour prior to Top of Descent
9. The use of eye shades, neck supports, and ear plugs is permitted

Assessment methods
The use of methods which necessitate the presence of one or more investigators in the cockpit was avoided, because presence of investigators on the flight deck might alter the regular flow of cockpit conversation and interaction (5). Therefore, in this study only 'pilot-friendly', non-interfering, and cost-effective objective and subjective methods were used to assess the effects of a 40-minutes controlled rest period on alertness and performance of both the resting and the waking pilot. Specific measures were chosen to evaluate sleep, alertness, and performance.

Data on cockpit rest and sleep
With respect to the controlled rest period in the cockpit, pilots used a Psion-3a palmtop computer to log subjectively estimated duration of the rest period, sleep latency, total sleep time, and quality of sleep. The quality of sleep was scored on a 5-point rating scale (Nap Quality Scale: very good, rather good, neither good nor bad, rather poor, very poor). Objective data on cockpit rest was recorded using an actigraph device. Using the event button, subjects marked beginning and end of rest and sleep periods. In addition, the quality of sleep during the pre-trip night (at home) and the stopover night was assessed (results not presented in this paper).

Sleepiness/alertness
The Stanford Sleepiness Scale (8) was used to assess subjective alertness throughout the trip (Table 2). This subjective rating scale has proven to be sensitive in detecting any significant increase in sleepiness or fatigue. Furthermore SSS measures showed to be highly correlated with flying performance and threshold of information processing speed during periods of intense fatigue (9).

Performance
During long cruise-flights, pilots have to sustain attention and to maintain vigilance under relatively monotonous conditions. These capacities are particularly vulnerable to the effects of fatigue and sleepiness (9,10).

Table 2: Stanford Sleepiness Scale (SSS)

1. Feeling active and vital; alert; wide awake
2. Functioning at a high level, but not at peak; able to concentrate
3. Relaxed; awake; not at full alertness; responsive
4. A little foggy; not at peak; let down
5. Foggy; beginning to lose interest in remaining awake; slowed dow.
6. Sleepy; prefer to be lying down; fighting sleep; woozy
7. Almost in reverie; sleep onset soon; losing struggle to remain awake

Therefore in this study, emphasis was laid on the assessment of vigilance. The performance task used in this study (VigTrack; Fig.1) is a dual-task, which measures vigilance performance under the continuous load of a compensatory tracking task (11). This task was successfully applied in studies on the effects of irregular early reporting times on alertness of pilots in short-haul operations (12), sedative effects of antihistamines, and alcohol (13,14). The VigTrack probes two important aspects of the behavioural capability of aircrew, and is not a measure of overall operational performance. However, high levels of performance on the VigTrack require sustained attention for 5 minutes, while attention is distracted by the tracking task. To the extent that attention and adequate tracking are critical features of many tasks involved in the safe operation of aircraft, the VigTrack data provide information about operational readiness and vigilance.

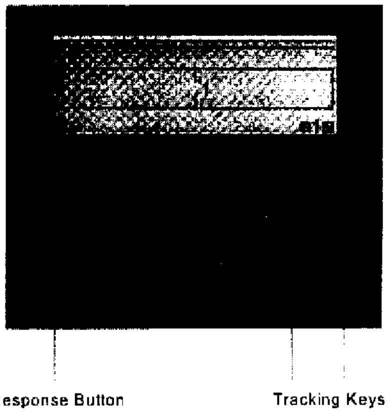

Fig. 1. Psion 3a: Vigilance and Tracking task (VigTrack)

Procedure and experimental design
A schematic overview of the procedure is presented in Table 3. Before the trip, pilots were instructed how to use the actigraph and the Psion-3a palmtop computer. They were trained on the performance task and briefed on the subjective rating procedures. Each pilot was equipped with his own actigraph and Psion-3a. Furthermore, it was decided which pilot was designated to have the controlled rest on the outbound flight and which on the inbound flight. Thus, during the two stretches of the trip, each of the pilots was once designated as 'resting pilot' and once as 'waking pilot'. During the outbound

flight, test sessions were performed just before and circa ¼ hour after the cockpit rest, and half an hour before top of descent. All sessions included SSS and VigTrack. In addition, in the 'post-rest' session the resting pilot had to rate quality of sleep during the rest period (NQS), while the waking pilot had to rate his sleepiness during this period ('Nap-SSS'). This rating was retrospective over the period in which the waking pilot had to maintain alertness while the resting pilot was resting. The test procedure during the inbound flight was identical to the procedure applied on outbound flights. Subjects had the opportunity to make written comments on non-standard flight circumstances and conditions that favoured or interfered with the quality of onboard rest (such as seat comfort, noise, cockpit visits). After their return at Amsterdam, actigraph and Psion-3a were collected and data were downloaded in a database.

Table 3. Overview of test procedure. SSS: Stanford Sleepiness Scale; VigTrack: vigilance and tracking task; NQS: Nap Quality Scale; Nap-SSS: SSS rating retrospective over rest period; rp = resting pilot, wp = waking pilot.

Before Trip	instruction and training on task
Outbound	
Pre-Rest	flight data / SSS / VigTrack
Post-Rest	NQS (rp) / Nap-SSS (wp) / SSS / VigTrack
Top of Descent	SSS / VigTrack
Inbound	
Pre-Rest	flight data / SSS / VigTrack
Post-Rest	NQS (rp) / Nap-SSS (wp) / SSS / VigTrack
Top of Descent	SSS / VigTrack

RESULTS

Timing of the controlled rest period

Subjects were free as to when the nap was planned during cruise-flight. The mean time period between take-off and the start of the nap was 04:16 hr (±00:54) on outbound flights, which is approximately after 53% of the total flight time. Inbound cockpit rest was planned 03:52 hr (±00:55) after take-off, which is after 55% of the total flight time.

No significant correlations could be demonstrated between the timing of the cockpit rest and parameters of sleep during the controlled rest period (NQS scores, sleep latency, total sleep time, and sleep efficiency).

Sleep during controlled rest on the flight deck

As appeared from the comments of the pilots, 18% of them complained about shortcomings of the cockpit seat, such as lack of leg space and limited recline, and explicitly mentioned the lack of a head rest on the seat as the reason for not being able to make optimum use of the controlled rest opportunity. Other comments were interference of rest by noise, turbulence, and cockpit visits by cabin crew. On outbound flights 48% and on inbound flights 41% of the pilots did not sleep at all during the controlled rest period. Characteristics of those pilots, who subjectively had any amount of sleep during the 40-minutes rest period are presented in Table 4.

No significant differences in nap sleep variables were found between outbound and inbound flights and no significant correlations could be demonstrated between subjective and actigraphy measures. On outbound flights 27% of the pilots rated the quality of sleep as rather good and 42% as rather poor or very poor. On inbound flights 18% rated quality as very good or rather good and 38% as rather poor or very poor.

Table 4. Characteristics of sleep during controlled rest on the flight deck: total rest time (TRT), sleep latency, total sleep time (TST), sleep efficiency, and sleep quality (NQS) as estimated by subjects and measured by actigraphy on outbound and inbound flights. Scores are presented as means (±SD).

	TRT (min)	latency (min)	TST (min)	efficiency (%)	NQS
OUTBOUND ✈					
subjective	37 (4.3)	12 (7.8)	19 (10.6)	51 (25.7)	3.0 (0.9)
actigraphy	39 (5.6)	3 (2.3)	16 (13.7)	69 (14.5)	
INBOUND ✈					
subjective	38 (5.0)	13 (7.4)	19 (9.3)	49 (21.3)	2.8 (0.8)
actigraphy	42 (7.5)	9 (12.4)	14 (12.7)	56 (20.6)	

Effects of cockpit rest

To assess the effects of the controlled rest on the flight deck, scores of the pre-rest session were used as reference values. Difference-scores were computed between post- and pre-rest scores. These scores represent the effect of the nap on alertness and performance as measured a ¼ hour after the rest period. To assess whether a controlled rest on the flight deck had beneficial effects on performance associated with critical phases of flight (approach and landing), also difference-scores between top of descent and pre-rest scores were computed. Mean difference-scores on sleepiness (ΔSSS), vigilance (Δ%omissions), and tracking (ΔRMS) are presented in Figs. 2, 3 and 4. On outbound flights, no significant difference in the post-rest ΔSSS (Fig. 2) scores was found between resting pilots and waking pilots, while at top of descent the difference was significant ($U=151$, $p<.001$): sleepiness in resting pilots had decreased, while sleepiness in waking pilots had slightly increased. On inbound flights, the difference in ΔSSS scores between the two groups was significant both at post-rest ($U=249$, $p<.05$) and top of descent ($U=139$, $p<.001$): sleepiness in resting pilots was not affected (post-rest) or had decreased (top of descent), while sleepiness in waking pilots had increased.

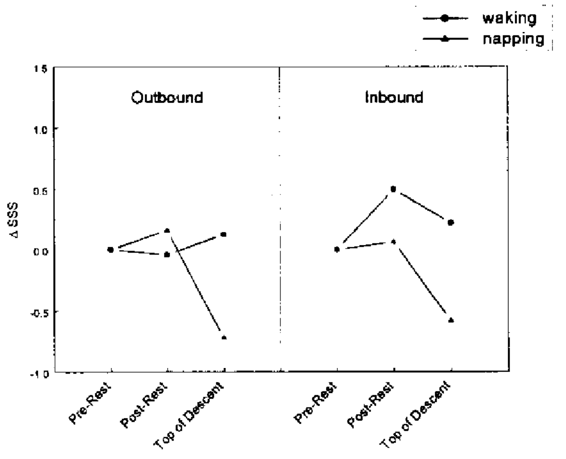

Fig. 2. Mean difference scores on sleepiness (ΔSSS) of resting and waking pilots for outbound and inbound flights.

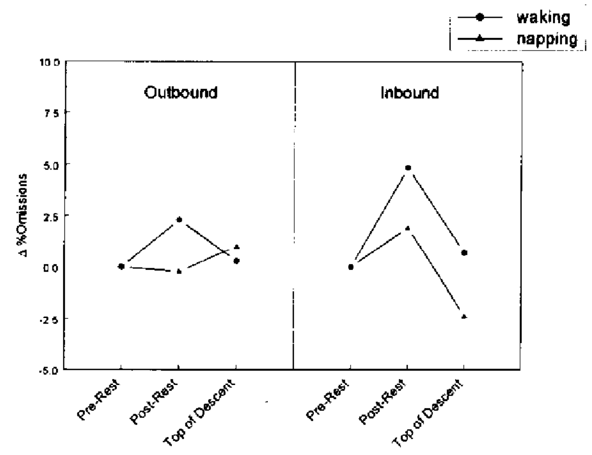

Fig. 3. Mean difference scores on vigilance (Δ %omissions) of resting and waking pilots for outbound and inbound flights.

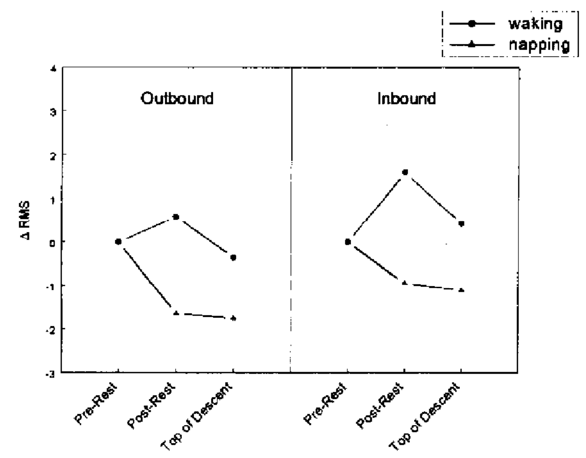

Fig. 4. Mean difference scores on tracking (ΔRMS) of resting and waking pilots for outbound and inbound flights.

Although resting pilots showed an overall better vigilance performance, no statistically significant differences were found (Fig. 3: Δ%omissions). Post-rest difference scores on tracking performance (Fig. 4: ΔRMS) showed significant differences between resting and waking pilots both on outbound ($F(1,47)=4.97$, $p<.031$) and inbound flights ($F(1,55)=7.97$, $p<.007$): resting pilots showed improved tracking performance after the rest, while performance of waking pilots had impaired. At top of descent, differences found were statistically not significant, although performance of resting pilots showed improvement while tracking performance of waking pilots remained on reference level.

To assess the effects of sleep per se, the resting pilots group was divided into two subgroups: sleepers (any amount of subjective sleep) and non-sleepers (no subjective sleep). Sleepers showed significantly lower sleepiness scores after the cockpit rest (inbound: $U=88$, $p<.01$) and at top of descent (out- and inbound: $U=40.5$ and 82.5 respectively, $p<.05$). Furthermore, it was observed that longer sleep duration resulted in lower sleepiness levels at top of descent ($r=-.59$, $p<.05$). No significant differences in performance between the two subgroups were observed.

Alertness of the waking pilot

During the period that his colleague was resting, the alertness of the waking pilot was assessed by means of a retrospective SSS rating (Nap-SSS); viz. at termination of the rest period the waking pilot was asked to rate his sleepiness during this preceding period. When comparing mean Nap-SSS scores with pre-rest, post-rest, and top of descent SSS scores, it was found that Nap-SSS scores were slightly higher (ns) on both outbound and inbound flights (outbound: 2.5, SD=±.96; inbound: 2.9, SD=±1.55.).The frequency distribution of Nap-SSS scores for outbound and inbound flights is presented in Fig. 5.

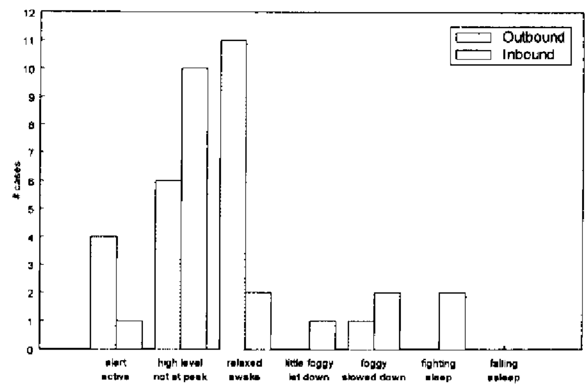

Fig. 5. Frequency distribution of Nap-SSS ratings for outbound and inbound flights.

On outbound flights 1 pilot was identified with a Nap-SSS score of 5 (foggy, slowed down) and on inbound flights there were 2 pilots who rated 5, and 2 pilots rated 6 (fighting sleep). Nap-SSS scores were significantly correlated with the quality and efficiency of the pre-trip and stopover sleep (with quality scores: $r=.27$, $p<.05$; with efficiency: $r=-.49$, $p<.05$). This indicates that good pre-trip sleep quality and efficiency are associated with less sleepiness (higher alertness) during the rest period. Furthermore, pre-rest sleepiness scores showed significant correlation with sleepiness of waking pilots during the rest period ($r=.58$, $p<.001$). On outbound flights, pre-flight and pre-rest tracking performance (RMS) was significantly correlated with Nap-SSS scores ($r=.46$, $p<.05$ and $r=.50$, $p<.05$ respectively). There was no relationship between the timing of the controlled rest period and the Nap-SSS scores.

CONCLUSIONS

1. A controlled rest period in the cockpit is a useful countermeasure for the effects of fatigue and sleepiness, as experienced by a majority of pilots engaged in long-haul flying. A 40-minutes rest period provides improvement in alertness and performance up to top of descent.

2. A substantial number of resting pilots did not sleep during their rest period. Pilots who slept showed more improvement of alertness and performance after the nap and before top of descent, than pilots who did not sleep during their rest period.

3. A number of pilots had difficulties in maintaining alertness during the rest period of their colleague pilot. Higher levels of sleepiness of the waking pilot during the rest period were associated with lower quality and efficiency of pre-flight sleep, lower pre-flight and pre-rest performance levels, and higher pre-rest sleepiness.

4. Data on total sleep time, quality and efficiency of pre-flight sleep, pre-flight and pre-rest performance, and pre-rest sleepiness are useful to predict the designated waking pilot's capacity to maintain a sufficient level of alertness during the controlled rest period.

OPERATIONAL ISSUES

Measures to improve sleep opportunities of the resting pilot

Pilots who slept showed more improvement of alertness and performance after the nap and before top of descent, than pilots who did not sleep during their rest period. Therefore, sleep opportunities should be optimized. The pilots in this study indicated, that measures which improve the comfort of the cockpit seat, such as fitting a head rest and improving reclination will lead to better opportunities for sleep during the rest period. Furthermore, disturbance of sleep due to noise should be limited by instructing cabin crew to carry out the necessary cockpit visits during the rest period as silently as possible, and by wearing suitable ear plugs. Designated resting pilots should avoid coffee before the rest period. Moreover, ample time should be taken for pre-rest briefings. Only a complete briefing will give a resting pilot the opportunity to 'reset' his mind and to get mentally 'ready for sleep'.

Measures to improve alertness of the waking pilot

It can be assumed that both pilots equally benefit from the preventive effects of a cockpit nap. In the context of maintaining optimal alertness in designated waking pilots, it should be emphasized that cockpit rest periods should be preplanned. Planning of rest periods at times, when maximal sleepiness of both pilots is anticipated, should be avoided. The sequence of rest periods should be determined by the needs of both pilots. The most fatigued pilot should use the first rest opportunity, to be taken at a time when the waking pilot will still be able to maintain his alertness on a sufficient level. After this rest period, the rested pilot will be better prepared, in terms of alertness and performance, for the next controlled rest period in which he will be designated as waking pilot.
The results of this study indicate that high quality and efficiency of pre-flight sleep will lead to higher levels of alertness in waking pilots. Therefore, optimal pre-flight sleep of sufficient duration (>8 hrs) should be pursued.
Further improvement of the ability to maintain sufficient levels of alertness during night flights can be achieved by increasing the level of illumination in the cockpit, while the resting pilot (using eye shades) is having a nap (15,16). In addition, coffee could be used to optimize alertness of the waking pilot (17).

Monitoring alertness of the waking pilot

An insufficient level of alertness of the designated waking pilot should be identified before the controlled rest period starts. This is important, because even if an effective cockpit alarming system would exist (which is at present not the case; 18), it would be hazardous to allow a pilot, whose alertness is insufficient, to be the only pilot to monitor the aircraft systems. When a pilot with degraded alertness, is designated as the waking pilot during the controlled rest period, he might still be able to satisfy a cockpit alarming system, while neglecting relevant tasks (18).
To identify the level of alertness/fitness before flights and before acting as the waking pilot during planned rest periods, it is recommended to use a 'Fit-to-Fly Checklist', which will be designed in analogy with the 'CFIT Checklist' of the Flight Safety Foundation (19). At present, most cockpit crew uses 'common sense' and CRM principles when planning a (unofficially tolerated) rest period during cruise flight. In most cases this 'common sense' will lead to a justified decision. However, the 'Fit-to-Fly Checklist' can provide a systematic and protocolized method to the process of decision making. Particularly in 'borderline' cases this method will be a useful tool for the flight deck crew. It is common practice that pilots have to check their flight systems at regular intervals, and it is remarkable that no mandate exists on checking personal fitness at regular intervals during a trip. For this purpose the 'Fit-to-Fly Checklist' will be developed.

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