TITLE: Jet-Lag Syndrome

TITLE: Sleep/Wakefulness Management in Continuous/Sustained Operations

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Barbara M. Stone
QINETIQ Centre for Human Sciences
Cody Technology Park
Building A50, Ively Road
Farnborough, Hampshire GU14 0LX
United Kingdom

ABSTRACT

Rapid travel across time zones leads to a lack of synchrony between the activity of the internal rhythm generating systems of an individual and the local social or environmental time cues of the new time zone. The internal circadian clock adapts slowly to this mismatch leading to the syndrome known as jet-lag. This syndrome is particularly characterised by sleep disturbances, reduced daytime alertness and performance, gastrointestinal symptoms and a general feeling of malaise. These symptoms are obviously undesirable for service personnel who are involved in intensive and sustained operations and who may have to deploy to a location involving travel across several time zones. Following north–south travel there are no problems with jet lag (Buck et al., 1989)

The adaptation of the circadian clock may take around one hour per day without countermeasures to adapt to a new time zone. However, around one third of travellers do not experience jet lag. In particular sleep disturbance is experienced by around 78% of subjects after a transmeridian flight whereas after 3 nights only around 30% of subjects experienced disturbance. In another study 40% of subjects reported subjective weakness.

There have been a number of studies on the effects of transmeridian flight on sleep. In general the severity of the sleep disturbance following transmeridian flight is related to the direction of travel and to the number of time zones crossed. Following eastward flight and when sleep is scheduled in advance of the home time zone there may be difficulties falling asleep and problems awakening in the morning. These difficulties may not be seen on the first night in the new time zone as if the flight involves an overnight flight without sleep. Such sleep problems may persist for several days and reductions in SWS and REM sleep may be present. After westward flights the sleep disturbance may only last for two or three days. Sleep quality is good in the first part of the night, with increased SWS on the first night associated with the long period without sleep. On subsequent nights an increase in REM sleep has been observed.

Recently reports of temporal lobe atrophy, spatial cognitive deficits in cabin crew chronically exposed to repetitive transmeridian flight have appeared in the literature. However, military personnel are unlikely to be subjected to frequent time zone changes.

Time zone travel in military operations

In scenarios involving sustained and continuous operations personnel may be required to be effective very soon after a rapid time zone transition. Moreover, soldiers, sailors and airmen may not have the time available for adaptation that is considered to be necessary for the efficient performance of business travellers or airline pilots.

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For example, during the Gulf War, many military units underwent a rapid transmeridian deployment and were then required to begin 24h operations as soon as they arrived (Ferrer et al., 1995) They were therefore faced with the problem of working throughout the 24 hour period against a background of jet-lag.

Circadian mechanisms.

Circadian rhythms are believed to be internally generated from the central pacemaker, the suprachiasmatic nucleus (SCN), in the hypothalamus. Most circadian rhythms also have an exogenous component due to a direct interaction with the environment. For example sleep lowers body temperature and exercise raises body temperature. Therefore the rhythm which we observe measure or experience is the sum of the endogenous and exogenous influences. The exogenous influences are referred to as *masking*. The problems of jet lag are considered to be due to the endogenous component of the rhythm.

The natural circadian rhythms of man are synchronised to the environmental and social cues of the environment. This synchronisation is maintained by cues, 'timegivers' or zeigebers.. The intrinsic tau or phase of the circadian pacemaker is considered to be around 24.2-24,3h. Daily phase adjustments are made to counteract the tendency of this pacemaker to delay and to keep human rhythms entrained to the 24h day. After transmeridian travel the synchronisers in the environment are no longer in synchrony with the circadian rhythm of the individual. It is the inability of the rhythms of the individual to adapt rapidly to a sudden shift of these external synchronisers that causes a short-term dysynchronisation or mismatch between the body and the environment. Light is considered to be the stronger synchroniser of circadian rhythms to the 24 hour day (Wildgruber et al., 1983, Czeisler, 1995)

Symptoms

After transmeridian flight this mismatch leads to a series of symptoms which in some individuals lead to a subjective loss of well-being and to objective disturbance in sleep and performance. This syndrome, known as jet-lag, is characterised by sleep disturbances, reduced daytime alertness and performance, gastrointestinal symptoms, loss of appetite, distortion of time and distance, loss of physical strength and a requirement to urinate during the night. and a general feeling of malaise. The organisation of the menstrual cycle in females may also be disturbed (Voge, 1996). Meals eaten out of phase with the internal clock may give rise to inappropriate pancreatic and metabolic responses, some of which may be long term risk factors for heart disease (Hampton et al., 1996). These symptoms are obviously undesirable for service personnel who are involved in intensive and sustained operations. Even if subjective symptoms are not present the rhythms of an individual may require several days to adapt to the new time zone. The jet lag phenomena was first described in detail by Strughold (1952) and comprehensively reviewed by Klein and Wegmann (1979).

The internal circadian clock adapts slowly to abrupt changes of time cues. The rate of adaptation has been reported to follow a number of models. Rates of one hour per day without countermeasures, or quicker adaptation during the first days have all been quoted. However, since the adaptation is highly dependent on the individual, to the direction of flight, to the number of time zones crossed, to exposure to environmental cues any simplistic formula is inappropriate. The direction of the time zone change is particularly important. In general adaptation after eastbound travel is much slower than after westbound flight. Gander et al. (1989) showed that it took several days for the acrophase of the temperature rhythm to come within one standard error of complete resynchronization after a 9h westward transition, and that the adaptation in an eastward direction took even longer. This differing rate of adaptation related to direction of travel is shown in table 1 (after Klein and Wegmann, 1979). This table also shows the differing rates of adaptation of various physiological and psychological variables. The average rates of adaptation do not take into account the swifter adaptation immediately after travel.

VARIABLE	WESTBOUND	EASTBOUND
Body temperature	60	39
Reaction time	150	74
Heart rate	90	60
Urinary 17-OHCS	47	32

Table 1. Shift rates after transmeridian flight in minutes per day

In addition to differing speed of adaptation depending on direction of travel, it is also relatively common for travellers to adapt in the 'wrong' direction, such as delaying 16h instead of advancing 8h. (Gundel and Wegmann, 1989)

Around one third of travellers do not experience jet lag. But for those who do it is particularly associated with disturbance in sleep patterns.

Sleep patterns

In studies in the United Kingdom the sleep and circadian rhythms of following both westward and eastward flight have been studied in volunteer subjects and in aircrew. In a joint study with the Henry Ford Hospital in Detroit the adaptation to a 5h shift in both directions was studied (Nicholson et al., 1986).

Healthy male volunteers were studied for two days before, for 8 days in Detroit, and after the return flight to London on an overnight flight they were studied for a further 5 nights and 4 days. Sleep was recorded by electroencephalography and sleepiness during the day was assessed by the multiple sleep latency test. The study also included a condition where a hypnotic was used to counteract the jet lag but another speaker will cover this topic and I will only consider the results with placebo. Sleep with placebo after westward and eastward flights were compared with sleep during the control period. On the first night after the westward flight subjects fell asleep more quickly, but there was more awake activity and drowsy sleep during the second part of the night. (Fig 1).

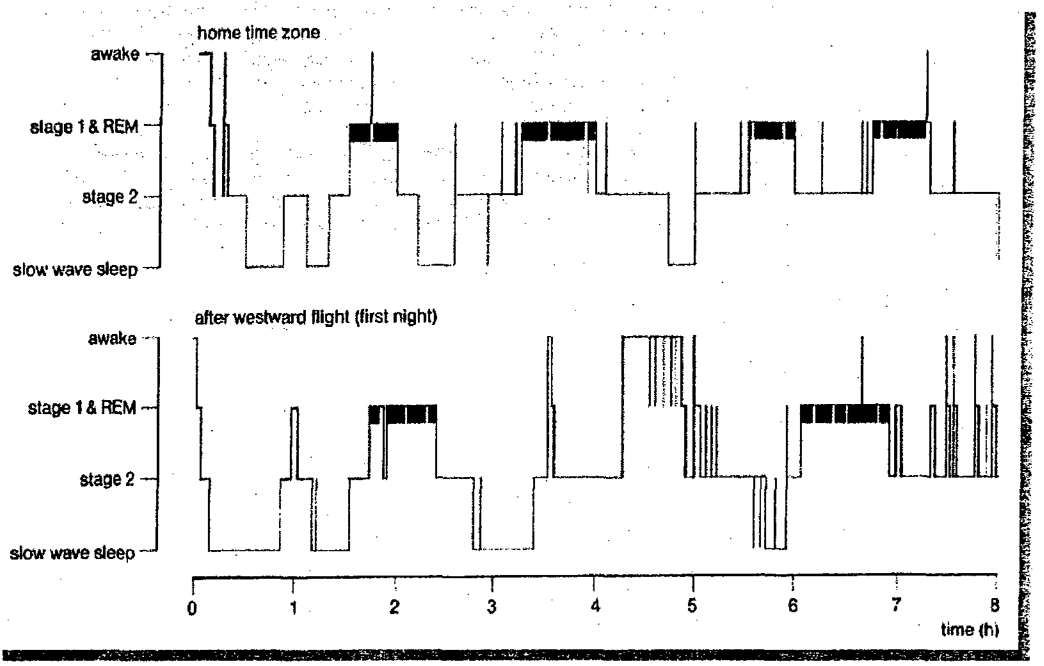

Figure 1
Sleep after five-hour westward flight. On the first night sleep onset was rapid but the second half of the night was disturbed.

The fast sleep onset reflects the requirement to sleep at a time equivalent to a late bedtime in the home time zone. The disturbed sleep in the second part of the night relates to the requirement to stay asleep around the equivalent of lunchtime in the home time zone. The late bedtime leads to a slight sleep deprivation that increases slow wave sleep and reduces the amount of Rapid Eye movement (REM) sleep. (Taub and Berger, 1973, Webb and Agnew 1971) During the second and third nights after westward flight s the ratio of REM to non-REM sleep was raised. This is due to the natural circadian rhythm in REM sleep that peaks towards the end of the normal sleep period. (Nicholson et al., 1984). This change in ratio was not seen on the first night because slow-wave sleep was increased. By the fourth night a normal sleep pattern was established, and together with the realignment of the rising phase of daytime alertness, which was seen at the same time, indicated that sleep had adapted to the new time zone.

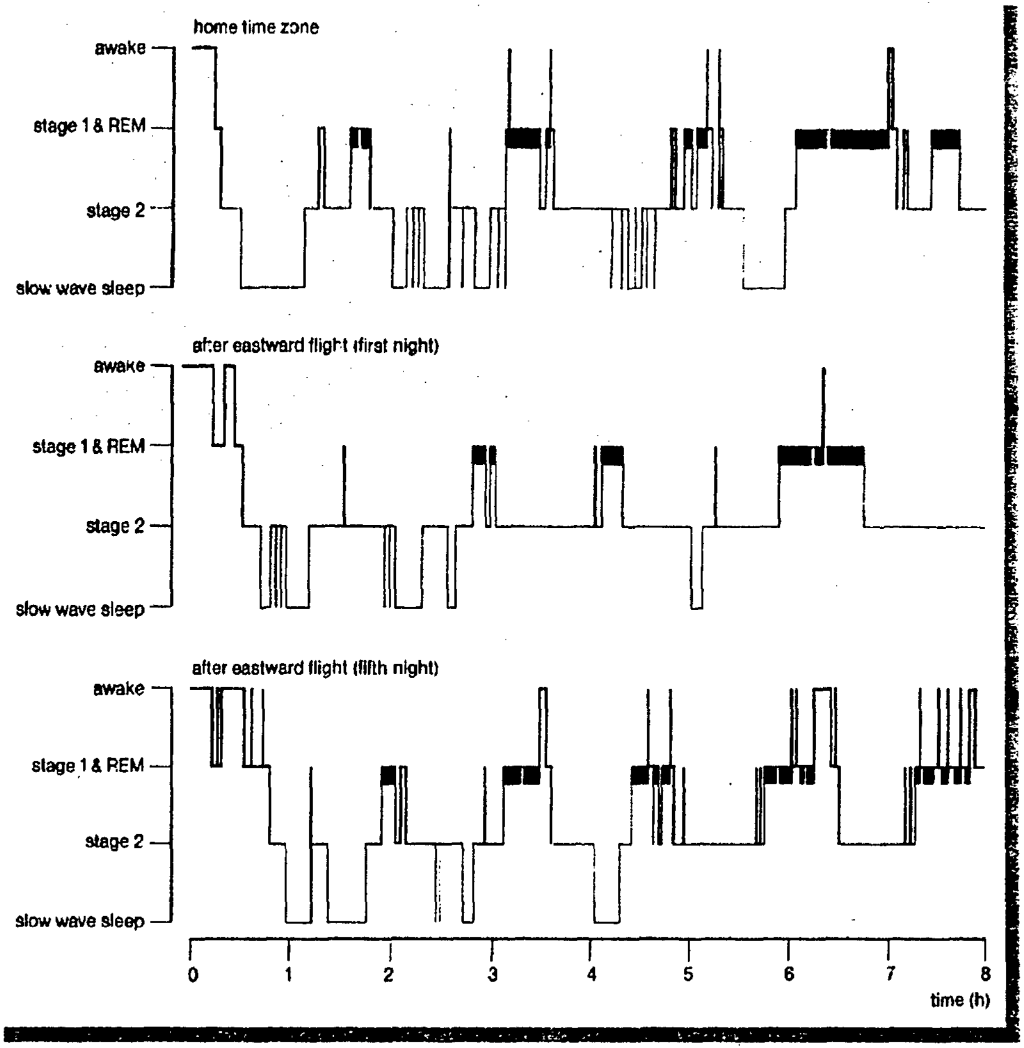

Figure 2
Sleep after five-hour eastward flight. On the first night sleep after an overnight flight sleep was not disturbed. On subsequent nights sleep onset was delayed and this was still apparent on the fifth night.

After eastward fight (Fig 2) the subjects slept better than before the flight. The eastward flight was overnight and this caused a delay of 19h in the first rest period, therefore on this first night the subjects were sleep deprived and slept quite well. The ratio of REM to non-REM sleep was also reduced. On the second night the subjects took longer to fall asleep reflecting the requirement to fall asleep at equivalent to 1830 in the time zone to which they were adapted. This difficulty in falling asleep persisted for the rest of the study. As well as difficulties in falling asleep, subjects also had reduced slow-wave sleep on the fourth night. On the fifth night which was the final recording night, total sleep time and sleep efficiency were reduced. The relatively slow adaptation after eastward flight may be related to the natural period of the circadian rhythm that is slightly longer than 24 hours. This study of a relatively small time zone change confirmed that adaptation to eastward travel is slower than adaptation to westward travel. By the end of five days back in the home time zone sleep and daytime alertness were not fully adapted after eastward flight and this slower adaptation is proportionately worse after a greater time-zone difference.

Gundel and Wegmann (1987) also demonstrated the longer adaptation after a 9h eastward transition, as well as large differences in the pattern of adaptation, with 3 out of 12 individuals experiencing a phase delay rather than a phase advance. Aircrew flying the polar route between London and Tokyo (Spencer et < biblio >) exhibited similar complex patterns of adaptation, with large individual differences.

In an attempt to predict the pattern of adaptation of aircrew and other travellers to rapid time-zone transitions, Gundel and Spencer (1992) developed a model based on the van der Pol equation. This equation has formed the basis for models of the human circadian system (Kronauer, 1984), and has been used to represent the effects of light on the circadian pacemaker (Kronauer, 1990). The model of Gundel and Spencer is based on the forced van der Pol equation:
The same authors have recently (1999) fitted the output from the model to body temperature data recorded before and immediately after a 10h eastward transition between London and Sydney. This 10h eastward time-zone change was chosen because simulations suggested that the pattern of adaptation would be most sensitive to changes in the parameter values making up the model. The fitting procedure also allowed for masking effects.

Twelve subjects were divided into two groups of 6, and each group completed an eastward flight between London, departing at 1300h local time, and Sydney, arriving at 1945h local time on the following day. Throughout the study, each subject kept a record of his daily activities in a logbook. This included the timing of sleep, meals, drinks, showers and exercise. Sydney is approximately 150° east of London, corresponding to a 10h difference. Recordings were made during a baseline period before departure, for a continuous 8-day period on arrival in Sydney and, after two days off, for a further two-day period before the return flight to London.
At 1min intervals throughout the study, rectal temperature was recorded on a Squirrel digital logger (Grant Instruments (Cambridge) Ltd). To reduce the effect of masking by activity and environmental changes, four 45min-rest periods were scheduled at approximately equal intervals during the day.
Only the temperature recordings during sleep and the rest periods were used for the estimation of circadian rhythmicity.
The adaptation of the 12 subjects to the 10-hour eastward transition is illustrated in Figure 3. This figure displays the estimates of acrophase on consecutive days after the flight, based on the estimated values of the individual sets of parameter values. Eleven subjects adapted by delaying his circadian clock, while only one adapted by advancing it. Those who delayed had adapted to within one hour of the new time zone after 8 days, whereas the one who advanced was adapted to within one hour after 6 days. During the time when the circadian acrophases were changing rapidly, the amplitudes of the rhythms were reduced to between 2% and 52% of the entrained values.

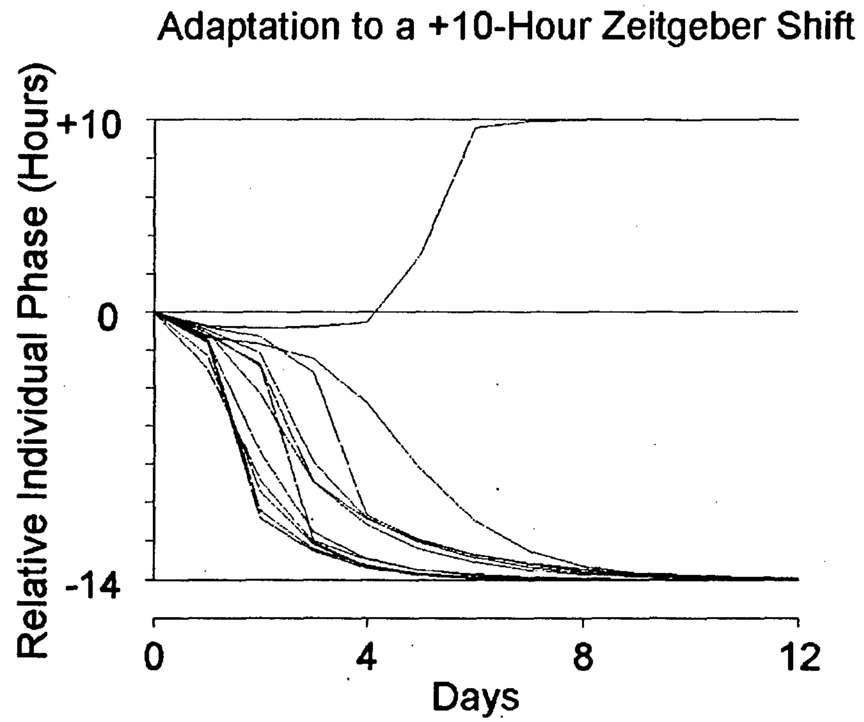

Figure 3
Circadian phases estimated from simulations using the estimated model parameters. Most of the twelve subjects respond to the 10-hour shift by a delay of the circadian time, the other one by an advance. Day 1 is the first day in the new time zone

The consequences of individual differences were also examined. Adaptation times were in a range between 1 and 11 days. However, weaker zeitgebers will generally lead to much longer adaptation times, and it has already been stressed that the zeitgebers in this study are likely to have been stronger than those that would normally be experienced, for example by aircrew on layover or military personnel on deployment. Since the prediction of adaptation times is dependent on the choice of the external force, estimates may need to be more conservative in real life situations when light exposure cannot be measured. This study emphasised the enormous individual differences in adaptation of the circadian. to long eastward time zone transitions. Performance rhythms also adaptation to a new time zone is also direction sensitive. Like physiological measures performance adapts more slowly after eastward flight and greater decrements in performance are observed after eastward travel. (Klein et al., 1970) The rate of adaptation also appears to be influenced by the complexity of the task. The more complex tasks are more sensitive to time zone crossings. This has obvious military implications.

The light-dark cycle is the principal time cue for resetting human circadian rhythms. If light of a suitable intensity and duration is administered both phase delay and phase advance of rhythms can be achieved. There are few field studies on the use or influence of light to speed adaptation to jet lag. In a military scenario light boxes may not be readily available! However, the judicious avoidance of light at particular times may be useful. For example, when travelling east over more than four or five time zones and arriving in the early morning, subjects will experience light, which opposes their adaptation. The use of blinds on the plane and eye masks on arrival may avoid this opposing light.

Long term health effects

It has been generally accepted that the main problem of the jet lag syndrome is the associated sleep disturbance. This sleep disturbance exacerbates the lowered performance associated with operating at the circadian low. Research has been focused on improving sleep by pharmacological and other means. Countermeasures to jet lag will be considered elsewhere. Apart from the sleep disturbance and the associated fatigue it was generally believed that jet lag is a mild inconvenience. However, in a recent study (Cho, (2001) has suggested that long term repeated time zone changes impair physiological and psychological health and induce stress. Cortisol levels in cabin crew after repeated exposure to transmeridian travel were higher than those exposed to short distance flights. (Cho et al., 2000) these higher cortisol levels were associated with cognitive deficits. It has been suggested that high cortisol levels lead to hippocampal atrophy and reduction in hippocampus dependent learning and memory. (Porter and Landfield, 1998, Lupien et al., 1998) In the study by Cho (2001) the log-term effect of repeated jet lag on the volume of the temporal lobe and hippocampus-dependent memory performance were tested in air stewardesses.

The temporal lobe was measured by MRI scan. The right temporal lobe was reported to be smaller in the group who had less than a five-day interval between outward transmeridian flights. These differences were reported to be unrelated to short-term sleep deprivation. The authors suggested that a longer recovery period may have eliminated the damage.

Military subjects are unlikely to be exposed to frequent time zone changes and therefore these findings are not yet a cause for concern in service personnel. However, if the changes are related to continuous circadian rhythm disturbance, this may have implications for military personnel who regularly work around the clock.

CONCLUSION

The performance of military personnel is likely to be compromised by transmeridian flight when they are required to deploy on arrival. One third of the personnel may suffer no ill effects. Eastward travel will cause more problems than westward travel and countermeasures should be considered and where necessary implemented.

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