THE PERCEIVED SEVERITY OF TRAVEL FATIGUE AND PERFORMANCE EFFECTS FOLLOWING TRANSMERIDIAN FLIGHTS

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ABSTRACT

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This two phase study examines the effects of transmeridian travel on airline passengers crossing 5 time zones or more. In Phase 1, a questionnaire was developed to assess the perceived severity of travel fatigue in 100 subjects flying east or west, and the findings correlated with their scores from the Circadian Type Inventory (CTI) and Composite Morningness Questionnaire (CMQ). The questionnaire provided an internally consistent measure of fatigue and established a correlation between the severity of travel fatigue and transmeridian flights, but failed to detect any significant difference between travel east or west. In addition, the CTI and CMQ scores did not assist in identifying those individuals most affected by travel fatigue. Phase 2 examined the influence of transmeridian travel on mood, affect, well-being and cognitive performance in 20 subjects who had previously participated in Phase 1. On each of five round-trips, subjects completed a computer based sleep diary and subjective rating scales of well-being using a pre-programmed Psion® Organiser. They were further assessed using tests of cognitive performance and data analysed from a total of 86 outbound journeys. Subjective rating scales for Alertness, Effectiveness and Mental Demand were all reduced following transmeridian travel although conversely ratings for Cheerfulness, Calmness, Appetite Disturbance and Physical Tiredness increased as did alcohol consumption. There was no effect on Length of Sleep although Quality of Sleep was lower on the first night after arrival overseas. Assessment of cognitive performance failed to demonstrate a Day effect but showed a marked Time of Day effect. Both Serial Choice Reaction Time and Memory Search Task scores were faster and the former more accurate over the Time Period 10^{00} to 15^{59}. There was also a clear Day$*$Time interaction in speed of response for both tests which persisted until seven days after the time zone shift.

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SECTION 1

CIRCADIAN RHYTHMS

AND TRAVEL FATIGUE

1.1 TIME ZONES

There are twenty four time zones covering the 360° of the globe and the idea that crossing these zones has an effect on the body appears frequently in the literature. Although there is a new time zone approximately every 15° of longitude, on studying an atlas, it becomes immediately apparent that these divisions do not cover the earth's surface in a straight line, pole to pole, or at 90° to every degree of latitude. In addition, time zones are man made and vary in width thereby representing arbitrary, albeit convenient methods of relating activities in different parts of the globe.

Given that these different time zones are arbitrary, then in themselves they possess no physical or physiological properties. However, the feelings of jet lag after a transmeridian flight are very real, and are due to numerous factors in addition to the crossing of time zones. These include pre-trip activities, in-trip activities, noise, vibration, low humidity and a new light/dark relationship. The effect of all these factors is that any performance change seen in the new time zone will be due to the fatigue of the journey coupled with the phase asymmetry of the circadian rhythms resultant on the new social and environmental cues.

1.2 AN OVERVIEW OF CIRCADIAN RHYTHMS

Circadian (Latin: *circa* - about; *diem* - day) rhythms are the daily rhythms which govern the body's physiological and psychological systems and which are synchronised with the 24 hour light/dark cycle. These systems follow a strict pattern with maximum and minimum levels occurring at specific times of day (Winget 1985). The time frame within which a natural endogenous biological rhythm operates is approximately 25 to 26 hours, not the 24 hour day in which we live (Shephard 1984) and while our body rhythms are synchronised to this night/day cycle by exogenous factors, it is far from clear whether this synchronisation has developed primarily by adaptation or evolution.

Endogenous rhythms are controlled by those factors which originate inside the body and not by environmental factors (Arendt 1982). In essence, endogenous rhythms persist in the absence of external cues such as clocks, light and meals, and despite a phase shift of the external cues following on the introduction of false time signals (eg. the use of clocks running on a 21 or 27 hour cycle) (Mills 1966).

Very few of the body's biological rhythms are completely endogenous although melatonin secretion is probably the best example. However, it is probable that cortisol production also falls into this category with a rhythm varying in length from 24-26 hours (Mills 1966). These biological rhythms are tuned to oscillate in phase with external cues, or zeitgebers (German: *zeit* - time; *geber* -given), which possess a 24 hour periodicity. In man the light/dark cycle associated with the solar day is the major zeitgeber.

The exogenous component of our rhythmic environment is dominated by the sleep/wake cycle, both directly, through the effects of sleep and exercise, and indirectly, through the association of our waking span with a more dynamic environment, social influences, postural changes and intakes of food and fluid (Minors 1990a).

The complex interactions between the environment, the body clock and the rhythms that it produces, enable rhythmic humans to integrate into a rhythmic environment. Not only are they "primed" during the day and partially "shut down" at night, but also their bodies can predict and prepare for environmental changes. They can therefore prepare for sleep during the falling phase of adrenaline, alertness and body temperature rhythms and prepare for the next day as these rhythms once again begin to rise.

However, the effects of possessing such a body clock can turn to our disadvantage if we change our pattern of sleep and activity such as when we cross several time zones; the resulting effects are the subject of this thesis and will be discussed in more detail in the succeeding sections.

1.3 THE BIOLOGICAL CLOCK

As outlined in Section 1.2, daily rhythms are under the control of an internal biological clock that, in the absence of any times cues, produces endogenous oscillations with a period slightly different from 24 hours. The biological clock responsible for the generation of circadian rhythms is normally synchronised to the 24 hour period by the fluctuating changes in the physical environment, primarily the 24 hour change in the light/dark cycle (Moore-Ede 1982).

Early experimental work indicated that the hypothalamus was the seat of the body clock as there was a loss of circadian rhythmicity in locomotor activity in rodents after ablation of the suprachiasmatic nucleus (SCN) (Rusak 1979). In addition, the uptake into the SCN of the antimetabolite, 2-deoxyglucose, was found to show circadian rhythmicity (Schwartz 1981). More recent work has tended to confirm that the SCN exhibits rhythmicity for an increasing range of variables and species, and a number of different afferent inputs have been identified together with a variety of neuro-transmitters (Card 1984). Thus, it should be possible to alter the circadian clock in the SCN with pharmacological agents that alter the activity of neural inputs to the SCN and/or neural activity within the SCN itself. Indeed, a variety of endogenous and exogenous substances have now been identified which can directly or indirectly speed up, slow down or induce a phase shift in circadian rhythms that are under the control of the SCN (Turek 1987).

However, one difficulty of interpretation is that such experiments might show no more than that the SCN is part of the pathway through which the clock like activity must pass. To investigate this dilemma, groups of hypothalamic cells including the SCN have been isolated surgically and left

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in situ (Inouye 1979) following which the cells continued to show circadian rhythmicity, whereas areas outside did not.

Unfortunately, the primacy of the body clock in the SCN has been compromised by a series of results indicating the need for more than one body clock:

i) Humans in free running experiments can show spontaneous internal desynchronisation, in which rhythms shows two periods simultaneously Wever (1979). Alternatively, internal desynchronisation may be induced by the progressive shortening or lengthening of successive "days" by means of artificial zeitgebers (Folkard 1983a), and

ii) SCN ablation does not always result in the loss of all rhythmicity (Rusak 1977).

Whether two or even more clocks exist within the brain is an issue that still needs resolution, but one solution is to suggest that the time-keeping role may be shared by two or more areas of the brain, one of which includes the SCN (Rosenwasser 1986). These areas are normally synchronised and together produce the endogenous component of circadian rhythms, but they may become separated functionally, as during internal desynchronisation, or one of them may take on a more dominant role, if for instance, the SCN is ablated (Minors 1990a).

Work is currently under way to identify the genes in the SCN which are instrumental in setting the circadian clock. So far the work has only been

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carried out in hamsters, but it is known that the genes in question, the *jun-B* and *C-fos* genes, respond to light and belong to a class known as the "early immediate genes" that are involved in the coupling of extracelluclar signals to changes in gene expression (Potera 1992). It is thought that these, or similar genes, affect the human circadian clock and provide a pathway for understanding the effect of light.

1.4 ZEITGEBERS

There is still some controversy as to whether the main zeitgeber in man is the light/dark cycle or social rhythms. It is likely that in a normal environment, a group of zeitgebers act simultaneously, some derived directly from the environment and others arising as a consequence of behaviourial responses (Minors 1990a). For example, the scenario could be proposed that individuals go to bed because they need a certain amount of sleep to prepare for the next day, and, because domestic and business commitments require them to be awake during the daytime, it is convenient to arrange waking time to coincide with daytime. Once the sleep/wake cycle has been established, all other potential zeitgebers (light/dark, feeding/fasting, social mixing/social isolation) are adjusted to coincide.

Despite this, recent work has concentrated upon the means by which a single zeitgeber might adjust the body clock in humans. It has been shown that pulses of bright light can adjust circadian rhythms of sleep, body temperature and plasma melatonin (Minors 1990b). The amount and direction of adjustment depends on when the pulse is given in relation to the phase of the body clock; pulses in the hours around waking advance the clock, whilst those in the hours around retiring, delay it. A pathway by which light might exert a direct effect upon the body is in the retino-hypothalamic tract which runs directly between the eyes and the SCN (Sadun 1984). Bright light suppresses the secretion of melatonin by the pineal gland in humans (Lewy 1980) and might produce a number of behaviourial changes, for example in eating, drinking and activity, that might themselves act as zeitgebers (Wurtman 1985). The detailed pathways and mechanisms by which the zeitgeber information is transmitted to and within the central nervous system remain to be established.

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With respect to transmeridian travel, the following generalisations have emerged from both field and laboratory studies of circadian rhythms of individuals undergoing adjustment to abrupt zeitgeber shifts (Aschoff 1975, Klein 1980a, Holley 1981, Gundel 1987):

i) The time required for complete resychronisation with a shifted zeitgeber depends on the magnitude of the phase shift, that is, the number of time zones crossed

ii) Resynchronisation is usually completed more rapidly after a westward flight (phase delay) than after an eastward flight (phase advance) of the same magnitude

iii) Relative direction of the flight (outbound vs homebound) and time of departure (day vs night) have minimal effect on the process of resynchronisation

iv) Circadian rhythms of different functions adjust at different rates. Thus during resynchronisation, the normal integration of physiological processes and behaviour is disrupted

v) The stronger the zeitgeber in the new time zone, the faster the rate of adjustment to local time although, in general, a phase adjustment of six hours occurs in the first 2 days following a flight with subsequent slow completion of resynchronisation at a rate of 0.5 to 1 hr/day

vi) In response to zeitgeber phase advances of six hours or more, some rhythms may adjust by advancing, whereas others resynchronise with a reciprocal delay (eg. an 18 hour delay in response to a 6 hour advance), and

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vii) There is clear variation in the time of resynchronisation between individuals. Extroverts (night people) have their peaks later in the day and adapt more easily to a phase delay than a phase advance (Winget 1985). Coupled to this is the factor of age. As age increases, there is a shift in the sleep cycle which leads the person to go to bed and rise earlier (Miles 1980). This has a great effect on the introverts whose rhythm for morning activity will become stronger (Horne 1977) therefore increasing the effect of any circadian dysrhythmia.

1.5 AN OVERVIEW OF TRAVEL FATIGUE

The label "jet lag" has been given to a variety of symptoms that passengers experience when travelling by aeroplane across several time zones and there are understood to be two main components to the syndrome:

i) The stress effects that extend from the physical and psychological aspects of the flight itself (Carruthers 1976), and

ii) Those effects that are due to the disruption of the internal biological clock (Winget 1984).

Both of these components will be considered in more detail and their relative importance examined.

Those effects that may be expected due to the flight itself include tiredness, malaise, nausea, headaches and aching joints. They seldom last more than a few hours after the end of the journey and are a function of the duration of the flight, rather than the number of time zones crossed (Monk 1987).

Other effects stem from the need to reset the biological clock to the new time zone. They are much longer lasting and for some individuals may persist for a week or more (Klein 1972a). The most intrusive problem is one of sleep disturbance, with periods of wakefulness occurring during the normal sleep pattern (Weitzman 1970). This will result in partial sleep deprivation with a consequent decrease in daytime alertness, increase in irritability and impairment of performance efficiency (Wilkinson 1966). However, it must be borne in mind that performance abilities and mood also have daily cycles and therefore may suffer simply as a function of the rhythm timing. Finally, there is the malaise that is a consequence of the disruption to the components of the biological clock which results in the phenomenon of desynchronisation (Aschoff 1975).

Considering the problem of desynchronisation in more detail, it is known that under normal conditions, many external cues can provide zeitgebers for the entrainment of rhythmic function. The light/dark cycle, temperature variation, social cues, and in man, knowledge of clock time are of particular importance. The range over which the normal 24 hour rhythm can be rapidly entrained to a new time zone is limited and it is this fact that leads to the rhythm disturbance encountered when travelling across time zones (Arendt 1982). A five hour time difference experienced on crossing the Atlantic, is for example, beyond this range of entrainment and the endogenous circadian system is forcibly desynchronised with its various components requiring different lengths of time (from days to weeks) to become entrained to local time (McFarland 1974). Interestingly, air crew do not show any specific sickness trends and, although highly selected and able to adapt to shifting flight schedules, it may be that their bodily rhythm characteristics are particularly robust. However, it would appear that some of the effects of desynchronisation may be refractory, as studies have shown that the menstrual cycle of some female cabin crew which are at first disturbed, subsequently stabilise after prolonged exposure to time zone shifts (Cameron 1969).

Under normal circumstances in man, the time taken for the adjustment of rhythms after a westward flight is known to be somewhat less (some authors quote 50% less) than that after an eastward flight. This directional asymmetry is explained by the fact that in isolation studies, the endogenous circadian system naturally adopts a longer day of about 25 hours and hence can more easily accommodate the phase delay required by westward flight. It is also known that the sleep/wake cycle may be disassociated from the 25 hour endogenous circadian period and this may explain why the cycle rapidly adjusts to local time zone shifts.

Other rhythms however, such as temperature and cortisol, lag by a variable number of days resulting in desynchronisation. The question of how important this desynchronisation is for well being, apart from the general effects of malaise, is a matter of conjecture, although, in a two year period, 186 patients were admitted from Heathrow Airport to a psychiatric hospital. It was found in these patients that affective illness was related to time zone change with depression being diagnosed significantly more often on flights from east to west (Jauhar 1982). It is known that manic depression and unipolar depression are both accompanied by disturbance of rhythmic function (Wehr 1981) and indeed there is evidence that transmeridian travel may trigger exacerbations in an individual known to suffer from endogenous depression (Tec 1981). Conversely, it has also been found that phase shifting the sleep/wake cycle alone in an depressive patient can be enough to induce temporary remission (Wehr 1979).

As an aside, the question of whether physical activity can reduce the period of desynchronisation is an interesting one. In the past it has been shown to exert a significant masking effect on rectal temperature and heart rate (Hildebrandt 1987), but more recently, experiments have been performed on hamsters where there light/dark cycle has been shifted abruptly by eight hours. Under normal circumstances, this would require a week or so to adjust, but if they are allowed to exercise on a clean, unfamiliar running wheel at the time of their normal period of activity in the new time zone, then they adjust almost immediately (Winfree 1987). It is not known whether this principle could be applicable to human beings but is undoubtedly worthy of investigation.

1.6 THE INTER-RELATIONSHIP BETWEEN CIRCADIAN RHYTHMS AND FATIGUE

In studying the effects of transmeridian travel on performance, it is necessary to be clear about the origin of any changes. There are two major determinants of performance, that is, the circadian rhythms, or naturally occurring variables, and fatigue, which is an integration of environmental effects (exogenous factors), personal constituents (endogenous factors), and life style (Cameron 1973, Hartman 1967).

Desynchronisation, as outlined previously, represents changes in circadian rhythm patterns and their inter-relationships in man, while fatigue embodies a combination of factors resulting in a state of decreased ability. However, fatigue and desynchronisation are inextricably linked to each other.

Performance in terms of psychomotor skills, symbol cancellation, reaction time, and digit summation, show a circadian rhythm (Klein 1976). Mental performance has been found to increase between 08^{00} and 14^{00} hours, only then to fall off as the day lengthens (Folkard 1975). However, mental perfromance is much more complex to measure and it has been shown that there is a general relationship between time of day and mental performance but that different aspects show their own temporal relationship (Klein 1979). One of these aspects is memory, and for this reason performance is often characterised on the basis of short or long term memory.

Performance is in itself a general term, and can be divided into three types: mental, psychomotor and behaviourial (Dodge 1982). Work shifts, practice, motivation, personality and disposition all influence behaviourial performance (Dodge 1982) and result in multiple changes during a 24 hour period, which in itself raises the question of whether behaviourial

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performance can be considered circadian.

Sleep/wake cycles, performance, body temperature and other physiological parameters all show their own rate of phase adjustment in the new time environment, but are generally similar in most individuals. However, these adjustments may be longer in some and absent in others (Klein 1976) and different in simulated conditions as opposed to time-travel conditions (Holley 1980). A state of internal dissociation between circadian rhythms is said to exist when the various parameters are realigning themselves to the new time environment. The resultant impairment in well-being is thought to be responsible for decreases in human performance (Klein 1972a, McFarland 1966).

Before considering the effect of fatigue, it is important to decide on a working definition. In general, fatigue refers to a common state whereby a person fails to meet a previous standard on a repeated task, that is, the individual has decreased ability. However, most studies have concentrated on the subjective aspects of fatigue, how to define it, measure it and standardise subjective checklists, rather than investigating objective measurements.

When reading about the effects of fatigue, one is invariably faced with a list of vague psychosomatic complaints such as headache, poor appetite, gastro-intestinal disruption, poor recent memory, depression and sleeplessness. Indeed, the same list of complaints will be found in a study of inadequate or disrupted sleep or in studies investigating the withdrawal from smoking, alcohol and other drugs. It has been found that fatigue effects and those of abnormal sleep are very similar, therefore making it extremely difficult to

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differentiate between the two.

Fatigue should therefore be considered in the light of a person's makeup and lifestyle (Cameron 1973, Hartman 1967). The effect of lifestyle is reinforced by the relationship between fatigue and sleep loss and this helps to show the importance of sleep patterns and habits in determining a person's current fatigue status. Fatigue has other causes besides sleep deficit and these other factors are essentially embedded in an individual's lifestyle and home circumstances. For instance, they may be irritable because of fatigue, illness, reduced motivation or domestic worries, but irrespective of the cause of their irritability, they may subsequently commit or omit an action which constitutes a performance decrement.

It is therefore apparent that sleep loss or disturbance produces reduced motivation and poorer performance. However, it is the automatic association of this condition with rhythmic desynchronisation which is misleading and there is some debate as to whether circadian sleep/wake cycle alterations or simple sleep deprivation are responsible for changes in performance (Dodge 1982). Indeed when such changes follow a period of abnormal sleep, for whatever reason, it is extremely difficult to discriminate between changes definitely attributable to either circadian rhythm effects or to fatigue effects. In these circumstances it has been suggested that the resulting performance changes should be related to the period of abnormal sleep or to its direct cause if known (Dodge 1982). Nonetheless, with respect to transmeridian travel, subjective symptomatology surveys have shown that although some symptoms of malaise disappear by the fifth day, some persisted even longer (Wright 1983). Those that diminished or disappeared by the fifth day included light-headedness, headache, dry mouth, sore throat, blocked nose and tense and aching muscles. Those symptoms still being reported were rhinitis, tiredness, sleepiness and irritability (Wright 1983, Desir 1981). In comparing eastward and westward flights, greater subjective discomfort and sleep disturbance was found with eastward flights as might be expected (Desir 1981).

1.7 THE EFFECT OF CIRCADIAN RHYTHMICITY AND TIME ZONE CHANGES ON PSYCHOLOGICAL PARAMETERS AND ATHLETIC PERFORMANCE

Most of the body's physiological functions exhibit circadian rhythmicity where the maximum and minimum functions occur at specific times of day. The rhythm may be expressed by oscillations in physiological systems such as body temperature, heart rate, hormone levels and responsiveness to either internal (neurotransmitter, electrolyte or metabolic substrates) or external (environmental factors, drugs, food or other stressors) stimuli (Winget 1985). The primary synchronizers are light/dark cycle alterations and periodic social contact or interaction (Holley 1981, Wever 1979).

There are two aspects of circadian rhythmicity which are important with regard to athletic and physical performance. One aspect is the time-dependent alteration in the levels of physiological processes, expressed either as circadian range (change from rhythm peak to trough) or circadian amplitude (change from daily mean level to the peak of the rhythm). Indeed, the sensitivity of the body to drugs such as ethanol, caffeine or medications is quite different at one time of day compared with another, which may then influence subsequent performance (Walker 1981).

The other aspect of circadian rhythmicity is the effect of the disruption of rhythms upon physical performance following transmeridian flights (Winget 1984). Circadian dysrhythmia may result in physical activity having to occur at the same time as the disturbance in the circadian systems which are controlling the individual's biological functions. This may result in a significant effect on performance efficiency with some aspects of physical performance being reduced whilst others increase (Taub 1974).

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The individual's circadian rhythms themselves are major sources of variability in performance and the range or amplitude increases with increasing task complexity (Klein 1977). The circadian range of performance rhythm oscillations is 10 - 30% of the daily mean (Klein 1976). Therefore the timing of athletic performance is extremely important, since a 10% change in performance is comparable to restricting sleep to 3 hours (Folkard 1983b) or ingestion of alcohol up to a level of 0.09% in blood (Folkard 1983b).

The presence of circadian rhythms in sensory, motor, psychomotor, perceptual and cognitive performance tasks is well documented (Winget 1985). However, the cognitive rhythms tend to peak earlier in the day than the sensory, motor or psychomotor tasks (Colquhoun 1982). Also, the memory load characteristics of a task influence task rhythmicity, since tasks requiring a high degree of memory processing peak about 8 hours earlier, and have lower rhythm amplitudes than low memory load tasks (Folkard 1983b). Rhythms of cognitive performance will affect athletic performance to the extent that it involves strategy, decision making and recall of complex coaching instructions during the competition. Long term memory recall (one week) is approximately 8% higher when the material is presented at 15^{00} hours than when it is presented at 09^{00} hours (Folkard 1979a). This has implications for the timing of coaching instructions and strategy since the 8% difference in memory retention is similar to the decrement induced by restricting sleep to 3 hours (Folkard 1977a).

Psychological parameters also exhibit circadian rhythms with self rated mood, well being, vigour and alertness all showing a sharp increase from 08^{00} - 10^{00}, followed by a gradual increase to a peak around 11^{30} - 14^{00}

(Folkard 1983c). These behaviourial factors are also important for athletic performance since they are indices of arousal which is a primary component of performance efficiency. The morning rise in these "arousal" factors may result from circadian rhythms in cortisol, adrenaline and noradrenaline which peak around 06^{00} - 10^{00} in the morning (Winget 1985). It is known that increased central nervous system levels of noradrenaline are associated with elevated mood and that cortisol may also have an alertness stimulation function (Halberg 1963). These hormones may also affect arousal through activation of metabolic processes. However, it is difficult to identify if there is a causal relationship between hormones contributing to arousal and performance, since subjective arousal, but not plasma adrenaline, correlates highly with performance measures (Froberg 1977) although when examining these measures in more detail, it is apparent that whereas the performance measure of vigilance appears to be functionally related to both body temperature and adrenaline level, digit span performance almost certainly is not (Folkard 1986).

The impact of psychological stressors upon performance depends upon arousal levels. It also depends on the degree of the individuals "perceived" control over the environment (Hockey 1983). In addition, there is also a strong association between motivation and arousal (Holding 1983). High motivation may overcome diurnal variation and produce a uniform 24 hour performance response (Alliusi 1967) which may be due to increased arousal.

There is a continuum of circadian rhythm patterns in humans which range from morning types, individuals who retire early in the evening and rise early in the morning, to evening types, who awake and retire relatively late in the day (Horne 1976, Horne 1977). There is a difference of 65 minutes in the body temperature rhythm peak times between morning and evening types (Horne 1977, Foret 1982), but morning types secrete significantly more adrenaline in the morning than evening types (Patkai 1971a) and the timing of mood and activity rhythms differ by several hours between distinct morning versus evening types.

Peak performance proficiency occurs later in the day in extroverts (Blake 1971) who are predominantly evening types (Patkai 1971b), than in introverts, who tend to be morning types with lower levels of arousal (Blake 1971). It may be that the impulsive nature of extroverts is the most important factor in the circadian pattern of efficiency (Hockey 1983). The morningness/eveningness dimension appears to be more important in differentiating individual circadian rhythm peak times than the extroversion/ introversion difference (Horne 1977). However, there are some concerns regarding the bases on which these conclusions have been drawn (Vidacek 1988). Firstly, very few studies have obtained measurements over an entire 24 hour period, and secondly, most studies of morningness/eveningness have compared relatively extreme groups, whilst those of introversion/ extroversion have not (Kerkhof 1985). Finally studies of extroversion have been primarily concerned with performance efficiency, whilst those of morningness have seldom included performance measures and have relied on subjective ratings of alertness.

As a result of this, Vidacek (1988) made a study examining trends over a complete 24 hour cycle for a range of performance and psychophysiological measures in students with extreme scores for both extroversion and morningness. The conclusion of his study provided support to Kerkhof's (1985) conclusion that morningness is more important than extroversion in determining the individual differences in the phase of circadian rhythms. However, more important from the practical viewpoint is the fact that Vidacek's (1988) results indicate that the magnitude of the phase difference between morning and evening types differs depending on the variables under consideration. Therefore, it is not possible to use morningness scores to predict relative efficiency on a given task at a given time unless a phase difference has previously been established for the task between morning and evening types.

Differences between male and female diurnal peak times of several urinary rhythms, including volume, electrolytes and serotonin metabolites indicate that there may be some inherent differences in internal circadian phase relationships between the sexes (Vernikos 1984, Vernikos 1977), but it is not evident if these differences have any significant effects on performance rhythms.

Following transmeridan flights across several time zones however, it has been shown that circadian performance rhythms desynchronise in a characteristic manner. Depending on the direction of flight, the phase of the rhythm is displaced, the range of the oscillation is reduced, and, often, the 24 hour mean is lower than under normal pre-flight conditions (Klein 1976). Decrements may be seen after a transition of six time zones. Indeed, it has been shown that women undergoing an eight hour phase shift exhibit a 17% to 38% decrement in short term memory, reaction time and visual search performance (Preston 1978).

Following a phase shift, circadian rhythms require a period of time for adaptation to the new time cues or adoption of a new sleep/wake schedule

(Winget 1984). There is considerable variation in the rate of readaptation of circadian rhythms between individuals which for a flight across six time zones, may vary from 1.7 to 17.9 days (Klein 1977, Rosenblatt 1973).

It is not clear what causes these different rates for the adjustment of rhythms following transmeridian flights, but it has been suggested that higher neural processes adapt faster than autonomic ones (Klein 1977). In addition, for a performance rhythm, a complex task exhibits a slower rate of adjustment than a simple one (Klein 1977), although this could simply reflect the relative magnitudes of the endogenous and exogenous components (Folkard 1993). For instance, speed on a four-choice serial reaction time task appears to be largely endogenously determined whereas that on a five-target Sternberg task is more dependant on exogenous factors (Folkard 1993).

Most flight experiments reported in the literature indicate that readaptation to a time zone change occurs about 30 - 50% faster following westward flights, which delay the timing of the circadian rhythm peaks, than after eastward flights, which advance the timing (Klein 1977). Performance levels are also more adversely affected following eastward flights than westward flights. Significant performance decrements lasting from 1 - 5 days have been observed in vigilance and in psychomotor, cognitive and athletic performance following eastward flights or phase advance of sleep/wake timing (Klein 1977, Klein 1980b, Taub 1974, Wright 1983). However, no significant decrements in performance appear to take place following westward flights or phase delay of the sleep/wake cycle (Klein 1977, Klein 1980b).

1.7

As outlined earlier, there is considerable individual variation in the effects of circadian dysrhythmia and the time necessary for readaptation. The morning type suffers more than the evening type from sleep disturbance resulting from westward transmeridian flight since the body temperature rhythms of morning types are phase advanced (peak earlier) relative to evening types (Holley 1981).

In extroverts (evening types), as compared with introverts (morning types) performance maxima and minima occur later within the circadian cycle (Klein 1980b). From this it follows that extroverts adapt more easily to a phase delay than to an advance shift. Observations on shift workers indicate that extroverts adapt approximately 50% faster to a delay shift than to an advance shift (Klein 1980b) this finding has been borne out in work by Colquhoun and Folkard (1978) which shows that there is a more rapid adjustment of the temperature rhythm to a 12 hour night shift (phase delay) in extroverts than in introverts. In addition, it appears that age influences adaptability to a change in the temporal structure of the environment and adjustment may become increasingly more difficult beyond 45 - 50 years of age (Hauty 1965).

1.8 THE EFFECT OF CIRCADIAN RHYTHMICITY AND TIME ZONE CHANGES ON INTELLECTUAL PERFORMANCE

Fluctuations in mental efficiency during the waking day have been studied for at least 100 years. In 1885 Ebbinghaus (1885) reported a consistent tendency for learning to be more rapid in the morning, an effect that he assumed to occur because "in the later hours of the day mental vigour and receptivity are less". However, Bechterew (1893) maintained that "the speed of the psychic processes is retarded in the morning and accelerated in the evening. The lowest speed occurred in the afternoon". This afternoon trough was also commented on by Kraeplin (1893) who related it to the midday meal. Kraeplin who conducted extensive research on the "work curve" also mentioned a "warm up" period in the morning and concluded that the decrements he observed were "no indication of (work) fatigue" since they "disappear after two to three hours, even when work is continued".

Thus, even in the earliest work, there are suggestions of two differing overall time-of-day trends and also of a "post lunch" effect. Fatigue was clearly accepted as being of importance, but its precise temporal manifestations appeared to be a matter of dispute. Work continued over the years and different workers appeared to come to different conclusions regarding the possible basic shapes of diurnal efficiency curves, namely a continuous rise; a continuous fall; a rise followed by a fall; and a fall followed by a rise. It was not until 1963 that Kleitman (1963) concluded that the true performance curve was that identified by Freeman and Hovland (1934) with a peak in the middle of the waking period.

Unfortunately, matters are not quite as simple as they appear. On a comparatively simple cognitive task for example, serial search, performance gets progressively faster over the day to peak at around 20^{00} hours (Blake 1967). This pattern parallels that of the temperature rhythm and led to the notion of a causal link between the temperature and performance rhythms. However, there is some indication that the trend over the day for a given task may depend more on the short term memory load involved in carrying out the task. Simple serial search involves little, if any memory component. However, when a memory load is added to this task, it is found that as memory load is increased, peak performance moves to an earlier time in the day (Folkard 1976). On more complex tasks, such as logical reasoning, performance tends to improve to about midday and then declines. The logical reasoning task is said to require the use of a working memory system which involves a number of different sub-systems, such as short term storage and processing throughput. It is likely that the pattern observed for this task, and others involving working memory, is the outcome of the combination of different trends. When the task is one which emphasises memory mechanisms, such as that required to memorise digital strings, then immediate recall of this material tends to be best early in the day and then steadily declines (Folkard 1980).

In Kleitmans's (1963) study, he also concluded that "most of the curves of performance can be brought into line with the known 24 hour body-temperature curves, allowing for individual skewing of the curves towards an earlier or later, rather than a mid-afternoon peak". This link between performance of simple tasks and the temperature rhythm, led to the view that either the circadian variation in temperature was responsible for circadian variations in performance (Kleitman 1963), or that there was some other mechanism which controlled both temperature and performance rhythms, for example, an underlying rhythm in arousal or sleepiness

(Colquhoun 1971).

When the findings are considered from studies involving a phase shift as a result of time zone transitions, it usually takes some time for the circadian systems to become synchronised to the new 24 hour routine and the rhythms in various processes adjust to this new routine at different rates. Following an 8 hour time shift, measurement on the 9th and 10th day after the shift show that performance on addition and verbal reasoning is better adjusted to the new routine than manual dexterity (Hughes 1976). Given that the first two tasks involve working memory, while the latter has a minimal memory load, it appears that the different rates of adjustment are a function of memory load.

Such dissociation of rhythms has also been observed in temporal isolation studies. When subjects are isolated from external time cues and their rhythms allowed to free run, they tend to follow a period of slightly more than 24 hours. Sometimes however, desynchrony spontaneously occurs and the sleep/wake cycle runs with a period of up to 30 hours while the temperature rhythm continues to run at about 25 hours (Folkard 1985a). This suggests that there may be more than one endogenous oscillator controlling the circadian system and evidence indicates that different parameters have different ranges of entrainment over which they run. For instance, temperature has a relatively narrow range of entrainment (22.3 - 26.9 hours) whilst the sleep/wake cycle has been observed to run at anything from 12 - 65 hours (Wever 1985a). To look at this in more detail, it is possible to induce internal desynchronisation when isolated subjects are provided with artificial zeitgebers which run progressively faster or slower (Wever 1983a). As the artificial day length changes, individual rhythms or groups of rhythms, break away from the artificial zeitgebers at their limit of entrainment and run free with their endogenous periodicity. Indeed, studies suggest that desynchrony between physiological and performance rhythms may be more common than at first realised (Folkard 1983a, Folkard 1985a). Work has shown that in subjects who were temporally isolated and then kept to a strict 24 hour routine using artificial zeitgebers for three weeks, the rhythms on some performance measures appear to follow a period of about 21 hours, even though the subjects physiological rhythms were all apparently synchronised to the 24 hour day. Finally, although models of the circadian system have tended to link the circadian rhythm in self-rated alertness to the sleep/wake cycle, it has been shown by Folkard in a shortening study (Folkard 1985b), that not only does the rhythm of subjective ratings of alertness become uncoupled from the sleep/wake cycle, but it also breaks away from the temperature rhythm.

It would therefore appear that current models of the circadian system which have been based on a limited range of physiological variables cannot account for rhythms in performance. For example, they do not explain:

i) The presence of 21 hour periodicity when neither the temperature or the sleep/wake cycle is following a 21 hour rhythm

ii) The presence of 21 hour periodicity in performance of subjects whose physiological rhythms are synchronised to a 24 hour cycle, and

iii) The limited range of entrainment and subsequent breakaway of the rhythm in feelings of alertness at an earlier stage than that seen for temperature

1.8

(Folkard 1985a).

To account for these findings, a number of different oscillations need to be proposed either working independently or as part of a single complex system that is capable of simultaneously producing multiple periodicities. If this is the case, then manipulations that affect the 24 hour period in temperature might also be expected to affect the 21 hour period in verbal reasoning (Folkard 1985a). Thus transmeridian air travel would seem to be the ideal situation in which to demonstrate the endogenous nature of a rhythm, and, indeed, has been used for just this purpose in the case of various physiological functions. Studies of performance rhythms are however, very few.

The work of Klein and Wegmann (1977) is the most comprehensive in this field and found that in general, complete phase adjustment of performance rhythms took up to 5 days or more. A faster mean adjustment rate was found with westbound (phase delay) than with eastbound (phase advance) flights.

Finally, Klein (1977) observed that the rhythms of different performance functions adjusted at different rates to the flight imposed phase shifts and suggested that the complexity of the task is an important variable in this adjustment. This has been borne out in later work (Monk 1978) which has showed that the rate of adjustment is at least partially dependent on the memory load of the task, even when this is manipulated within a single test. Klein also advanced the hypothesis that the rate of adjustment of a performance rhythm in this situation, is in part dependent on its basic stability in the pre-flight phase, that is, the more pronounced the rhythm, the longer it takes to adjust.

It would appear therefore, that performance on a wide range of tasks varies considerably at different times within the waking day in such a way as to strongly suggest the presence of an underlying circadian rhythm in the processes controlling the performance.

1.9 THE EFFECT OF CIRCADIAN RHYTHMICITY ON HUMAN MEMORY

It was originally postulated by Gates (1916) that there was a circadian rhythm of sleep and wakefulness, with wakefulness highest in the mid-afternoon. This has been examined by looking at the effects of time of day on memory, with most studies concentrating on immediate retention. One of the most popular immediate memory tasks has been the digit-span technique. In this method, varying length lists of random digits are read out to a subject at a rate of one digit per second. At the end of each list, the subject is required to repeat the numbers back as accurately as possible. A subject's digit span is taken as the maximum list length that is successfully repeated back, and usually ranges between five and nine digits. Although this task is artificial, and bears little resemblance to everyday memory tasks, digit span is known to correlate well with measured intelligence. Under normal testing conditions, the evidence on immediate memory for digit strings demonstrates a constant improvement from early to mid-morning (about 10.30 am) followed by a linear (and rather greater) decrease over most of the rest of the working day (Folkard 1982).

Other studies on immediate memory have used word lists or even prose, the latter showing a different trend to that of digit strings, in that it fails to show an improvement from early to mid-morning. A possible explanation for this difference is that the retention of prose is in some sense more difficult than the digit span, and hence has a lower optimal level of arousal. Alternatively, the difference may reflect the fact that whereas people are highly practised in remembering information presented as prose, few people have developed sophisticated strategies for remembering strings of random digits.

Irrespective of the underlying cause of these differences, it is important to emphasise that performance on a range of memory tasks is indeed affected by time of day. It would appear that the overall quantitative trends across the day reflect qualitative changes in the way in which subjects process information. As a result, conclusions drawn from a study at any given time, may only be valid for that particular time of day (Folkard 1982).

1.10 THE EFFECT OF LIGHT ON TRAVEL FATIGUE

Adjustment to local time after a transmeridian flight is equivalent to resynchronisation of the circadian system to a new phase following a shift in the zeitgeber. This process can take as many as twelve days following a nine hour time shift (Halberg 1971). How long the process takes depends on the strength of the zeitgeber and the magnitude of the phase shift (Aschoff 1975). It is known that the cycle of light and darkness is the most powerful zeitgeber for circadian rhythms in animals, but the human circadian system has long been considered insensitive to light (Czeisler 1981). However, it has now been shown that, firstly, high intensity light may affect human melatonin production (Lewy 1980), and that secondly, it may also entrain the human circadian temperature rhythm (Wever 1983b). Sensitivity of the melatonin response requires light to be of intensities exceeding 1000 to 2000 lux (Lewy 1980). Outdoor intensities in daytime exceed this level (Daan 1975), but conditions of artificial illumination are usually sub-threshold and therefore exert only a marginal influence on the circadian systems in humans.

In addition to this, for light itself to actually be effective in the entrainment of human circadian rhythms, its intensity needs to be greater still and to exceed a threshold of about 3000 lux (Wever 1985b). Such intensities are not normally reached within closed rooms, either by natural light, or by artificial illumination. Such intensities rather are only present in the open air (and even then only on days that are not too cloudy), or under very special artificial illumination. Once a light intensity of this level is exceeded, the physical stimulus is stronger than any known behavioural impulse and certainly much stronger than any other physical stimulus including light of lower intensities. The knowledge of the strong effectiveness of bright light on human circadian rhythms could have practical implications in the management of jet lag but for this to work, subjects will need to be exposed to very bright light (greater than 3000 lux) for at least three hours.

Attempts have been made to quantify the amount of light exposure required (Daan 1984) and it has been found that light exposure after westward flights over x times zones should begin at x hours before sunset and should last for a maximum of six hours. Extremely long westward travel should be treated as an eastward journey over (24 - x) time zones. For eastward travel, daylight exposure should begin at sunrise if x is less than or equal to six time zones and at (x - 6) hours after sunrise if x is greater than six time zones. Eastward flight over twelve or more time zones should probably be treated as a westward flight over (24 - x) time zones because the free running circadian period is longer than 24 hours and therefore more easily re-entrained by phase delay (Aschoff 1975).

1.11 THE EFFECT OF HORMONE SECRETION ON TRAVEL FATIGUE

It is clear that rapid transmeridian flights induce many behavioural and biological changes. Since the endocrine system plays a key role in the adaptation to environmental variations, it is possible that disruptions in the temporal organisation of hormone secretion may be involved in the pathogenesis of the jet lag syndrome.

Healthy male subjects were studied during a round trip by subsonic aircraft from Brussels to Chicago (Desir 1981, Fevre-Montange 1981, Desir 1982, Golstein 1983, Van Cauter 1981). It was found that the periods of maximal and minimal secretion of ACTH and cortisol adapted differently to the time shifts, suggesting that the various components of pituitary-adrenal periodicity are under different controls.

Jet lag failed to produce quantitative secretory alterations for ACTH, cortisol and prolactin. In particular, no significant changes were observed in the 24 hour mean levels, the amplitude of the circadian rhythms, or the frequency and global magnitude of episodic fluctuations in these hormones. In contrast, decreased 24 hour mean levels of plasma melatonin were observed after the westward shift (Desir 1983).

No consistent correlation was found between disturbances of the pituitary-adrenal periodicity and the level of psychological discomfort. However, an endogenous, non-sleep-dependent, circadian periodicity of plasma prolactin was detected in the profiles obtained after the flights, as well as in control studies involving simple sleep deprivation, challenging the concept that the night time prolactin rise is purely dependent on sleep (Desir 1983).

1.12 THE EFFECT OF MELATONIN ON TRAVEL FATIGUE

The epiphysis cerebri or pineal organ (so called in man because it resembles a pineapple) is part of the central nervous system, but is largely driven by sympathetic nerves. In 1958, melatonin was isolated from the pineal organ (Lerner 1958) and was regarded as the hormone of the gland. It is still considered as such, but the gland produces several other substances in addition which may equally well qualify as hormones and may even be more important functionally. Melatonin is synthesised from tryptophan with serotonin being an intermediate step in its biosynthesis. Serotonin, an important neurotransmitter, is therefore present in high concentrations in the pineal gland and enzymes for melatonin production have been shown to occur both in the gland and the retina (Meyer 1988).

Melatonin secretion has a biphasic pattern. Plasma levels are low at about noon and peak at about midnight. This rhythm is apparently generated by, and entrained to, the light/dark cycle through the suprachiasmatic nuclei. The surge in melatonin secretion entrained to the dark part of the circadian cycle may be inhibited by:

i) Change in the environmental light intensity that reaches the eyes

ii) Drugs, and

iii) Superior cervical ganglionectomy as the gland is largely driven by post-gangliotic nerve fibres (Meyer 1980, Binkley 1983,Vaughan 1984).

Over the last decade it has become apparent that the pineal gland plays an important part in behaviour (particularly in cyclical behavioural activity such as sleep and sleepiness), in directional orientation and in visual acuity.

1.12

Volunteers maintained on high plasma melatonin levels by oral dosing with 2mg of melatonin complained of early evening tiredness and sleepiness (Arendt 1984). Other studies have shown that relatively low oral doses of melatonin, three times a day, given to normal young adults, produce demonstrable subjective behavioural responses, changes in performance, feelings of sleepiness and reduced total motor activity (Lieberman 1984, Wurtman 1985). The ability of exogenous melatonin to produce sleepiness or even to induce sleep, plus the surge in endogenous melatonin at a time of day when people tend to become sleepy, raises the possibility that one of its physiological functions has to do with the timing of sleep.

With regard to jet lag, desynchronisation of the special senses plays an important role, and it would appear that the pineal gland is concerned with sense of direction and depth perception (Bayliss 1985, Theron 1984). To test the effectiveness of melatonin in the management of jet lag, double-blind placebo-controlled studies have been performed using 5mg of melatonin on subjects travelling between San Francisco and London (Arendt 1987) and between Auckland and London and return (Petrie 1989). Melatonin appears to significantly improve subjective ratings and feelings of jet lag (Arendt 1987, Petrie 1989); to significantly improve sleep quality (Arendt 1987); to reduce the time taken to establish a normal sleep pattern (Petrie 1989); to reduce tiredness during the day (Petrie 1989); and to reduce the time to reach normal energy levels (Petrie 1989). Melatonin treated subjects also tend to be more alert than placebo subjects, especially at bedtime (Arendt 1987). Interestingly, in the Auckland study, for all subjects the jet lag was more severe on the westward (return) journey than on the eastward (outward) journey. This may have been an artefact of the homeward journey because of the return to a more demanding and less exciting environment for the subjects, but it is possible, that over large numbers of time zones, part of the action of melatonin is to specify the direction of re-entrainment.

To examine this in more detail, Lewy (1992) found that a physiological dose of orally administered melatonin shifted the circadian rhythm in humans according to a phase response curve that is almost opposite in phase to that for light exposure. Interestingly, he also found that melatonin delayed circadian rhythms when administered in the morning and advanced them when administered in the afternoon or early evening.

In general, studies on the effects of melatonin in jet lag have established that it hastens the adaptation of sleep and of a number of hormonal and behavioural rhythmic variables to a rapid time zone change. It is known to be more effective in alleviating subjective feelings of jet lag following a journey of seven or more time zones than over shorter distances and it is probably more effective eastwards compared to westwards. No sex or age differences in response have been reported (Arendt 1992).

A minority of subjects taking melatonin have reported feeling more "jet lagged" following the drug and it is likely that the timing of administration in relation to individual circadian phase is very important, together with some control of exposure to ambient and natural light.

Melatonin appears therefore to have a therapeutic potential for alleviating jet lag. However, a further study looking at the effects of a similar dose (5mg) of melatonin on the electrocardiogram and simple reaction time responses (Wynn 1988) has shown that melatonin has the effect of lengthening the R-R interval, the period between the peak of the P wave and the onset of the R wave and the interval between the onset of the R wave and the peak of the T wave although the natural evening increase in melatonin also appears to have the same effects. Finally, analyses of the simple reaction time test responses to both visual and auditory stimuli, imply that the responses may also be lengthened by melatonin.

1.13 THE EFFECT OF HYPNOTICS ON TRAVEL FATIGUE

Abnormal timing of the various circadian rhythms has been associated with at least some forms of depression and disturbances of the sleep/wake cycle (Czeisler 1980, Moore-Ede 1982). The clock involved in the generation of many of the circadian rhythms is located in the hypothalamic suprachiasmatic nucleus (SCN). A number of afferent inputs to the SCN have been identified and a variety of neurotransmitters have been localised within it (Card 1984). Thus it should be possible to alter the circadian clock in the SCN with pharmacological agents that alter the activity of neural inputs to, or neural activity within, the SCN. Indeed, a variety of endogenous and exogenous substances have now been identified which can directly or indirectly speed up, slow down or induce a phase shift in circadian rhythms that are under the control of the SCN (Turek 1987).

As our knowledge of the nature of sleep disturbances increases, the appropriate role for hypnotics in the management of insomnia becomes clearer. It is well known that hypnotics may reduce the time required to fall asleep, but their place in the management of those who are unable to stay asleep is less certain. Hypnotics are most appropriately used to treat temporary sleep difficulties such as those which may occur with transmeridian travel (Nicholson 1990), but, before prescribing a drug it is important to weigh up the benefits against possible adverse effects. Particularly important amongst these is the impairment of skills such as driving and decision-making or the carrying out of certain tasks.

In the past, it has been considered that the habitual use of any drug which impairs performance should preclude "employment from certain occupations". However, with the greater knowledge now available in therapeutics, this view is less concrete and provided that the drug is free from residual effects, then it may be made available to most occupational groups. The duration of action of a drug depends on its absorption, distribution and elimination. To assist an individual to fall asleep, the absorption rate of a hypnotic drug must be rapid enough to ensure that the plasma levels peak soon after ingestion. Following absorption, the drug is distributed around the body and a hypnotic generally produces an effect for as long as the plasma concentration remains above a certain level. The duration of action will be short if this level is related to the distribution phase, but may be much longer if it is related to the elimination phase (Nicholson 1990).

Many hypnotics have a pharmacokinetic profile in which the parts played by distribution and elimination in the decline in plasma concentration are clear although it must be borne in mind that the continued daily ingestion of such drugs may lead to accumulation if elimination is relatively slow. However, Temazepam, which is a derivative of Diazepam, has a distribution phase similar to its parent compound, but it is more rapidly eliminated, does not have a slowly eliminated metabolite, and therefore does not lead to accumulation (Nicholson 1990).

Significant interest has in the past centred on even more rapidly eliminated drugs, some with half-lives of two to three hours, such as Triazolam, although such rapid elimination is less likely to result in sustained sleep. It would appear that achieving sustained sleep without residual effects the next day, using drugs in which the elimination phase is predominant, requires a pharmacokinetic profile with a mean elimination half-life of approximately five hours (Nicholson 1990).

1.13

The benzodiazepines are at present the drug treatment of choice for the management of insomnia (Office of Medical Applications of Research, Consensus Conference 1984) and are thought to act by potentiating the action of the neurotransmitter gamma-aminobutyric acid (GABA), which is widely distributed in the central nervous system (Muller 1982). It would also appear that both cell bodies and axons containing GABA are present within the bilaterally-paired suprachiasmatic nuclei (Card 1984, Van den Pol 1985). These findings raise the possibility that the benzodiazepines may have a fundamental effect on the central circadian pacemaker. Indeed, it has been found that the acute administration of Triazolam can induce a phase shift in the circadian rhythm of locomotor activity (Turek 1986, Turek 1988a, Turek 1989) and pituitary luteinising hormone release (Turek 1988a, Turek 1989) in hamsters. In addition, following a shift in the light/dark cycle, a single injection of Triazolam can facilitate the time it takes for the activity rhythm to be resynchronised to the new lighting schedule (Turek 1988a, Turek 1989, Turek 1988b). More than this, it is also important to bear in mind that the phase shifting effect on the biological clock is dependent on the circadian time of administration. Hence, any attempt to design an appropriate drug regime that will enhance sleep, as well as shorten the time needed for re-entrainment of the circadian system following a shift in the sleep/wake cycle, must take into account both the direction of the phase shift and the circadian time of drug administration (Turek 1986). Indeed, preliminary studies indicate that the administration of Triazolam at appropriate times may facilitate the adaptation of human endocrine rhythms to an eight-hour delay shift of the sleep/wake cycle (Van Cauter 1987).

Sleep may be disturbed and alertness impaired for several days after a transmeridian flight and re-aligns slowly according to the local pattern of rest and activity. Resynchronisation may take as long as six days after westward flights and as many as eleven days after eastward flights. This difference in time required to adapt to a new time zone after eastward and westward flights is related to the fact that the period of innate circadian rhythmicity is longer than that of the normal light/dark cycle.

Any hypnotic that is to be used during a flight should be tested beforehand to ensure that the patient's response is appropriate. This is important to consider as a recognised side effect of benzodiazepines is anterograde amnesia (Harvey 1985), although this is usually seen only after intravenous administration. However, cases have been documented after oral doses of Triazolam in the therapeutic range have been taken together with alcohol (Morris 1987).

As outlined above, sleep difficulties following transmeridian flights vary according to the direction of the flight. Those that occur following eastward flights appear to be relatively persistent, whereas those that occur after westward flights are much less marked and usually persist for no more than one or two days. The inability to stay asleep may be overcome if a hypnotic is taken the first night or two after flying westward and for several nights after flying eastward. The type of hypnotic needed will be the one that is likely to sustain sleep without residual sequelae and that is free from accumulation on daily ingestion. The hypnotic most likely to meet these requirements is rapidly rather than ultra-rapidly eliminated and for this reason, the benzodiazepine Temazepam has been used successfully for many years in the management of sleep disturbances in civil aircrews (Nicholson 1990).

1.14 THE EFFECT OF SLEEP DISTURBANCE ON TRAVEL FATIGUE

Transmeridian flights are known to lead to sleep disturbance due to changes in the routine of sleep and wakefulness (Nicholson 1972, Preston 1973) and it is thought that there is a link between the abnormal phasing of circadian rhythms and what is commonly called "jet lag syndrome". In humans the inherent period of circadian rhythmicity is on average 25 hours (Wever 1979). However when we live under normal conditions, the internal circadian oscillation is usually synchronised to a period of 24 hours (Minors 1992) although there is some evidence that this is not always the case. This adjustment is achieved by means of rhythmic cues from the external world, for example, the alteration of light and dark, the sleep/wake cycle, and the social influences (Wever 1979, Minors 1981a, Moore-Ede 1982).

When this synchrony is upset by time zone transitions then there will be occasions when work and sleep are being attempted at inappropriate times of the circadian cycle. That is sleep, and as a consequence, activity, meals, light and social influences, will have to be taken when there is opportunity, rather than when it may be ideal. In such circumstances sleep is often taken not over a single period of 8 hours but rather split into several episodes.

If subjects are placed in temporal isolation then the onset of sleep appears to occur preferentially near the temperature minimum (Winfree 1982a), but in the absence of cues, the fixed timing of sleep/wake transitions relative to temperature extremes proves short-lived. It appears that body temperature, plasma cortisol and REM sleep are governed by one internal timer and sleep/wake alternation and growth hormone secretion by another (Weitzman 1979, Weitzman 1981a, Weitzman 1981b). The alterations of sleep and waking eventually get out of step with the temperature cycle and this occurs more readily in older people (Wever 1979, Wever 1982). As isolation experiments show, the onset of each successive sleep becomes later with respect to the 25 hour fluctuations of body temperature (Winfree 1982b). At some point, the person elects to stay awake well past the temperature minimum which usually forecasts impending sleep onset. The subject is unaware that he has done anything unusual, and remains awake without sensing that he has missed a night's sleep. When the subject then finally goes to bed, he may sleep longer than usual, but this is unpredictable (Akerstedt 1981b). It would appear that the duration of sleep is governed more by the timing of sleep onset within the temperature cycle than by the duration of prior wakefulness (Czeisler 1980).

Sleep after long haul flights is likely to be influenced by a variety of factors, including the timing of the flight and the imposed change in the timing of sleep as determined by the direction of travel. Work has been undertaken to analyse sleep quality following long haul flights by using a wrist-worn ambulatory monitor to study bedtime motor activity (Buck 1989), and this indicates that the quality of sleep is reduced following transmeridian flights but is unaffected by north/south flights. Further studies have been performed looking specifically at the effects of transatlantic flights (Nicholson 1986a). Following a westward flight leading to a delay of 5 hours to the first rest period, subjects fell asleep more quickly, and slept more deeply, which was partly attributable to sleep deprivation (Taub 1973, Webb 1971), although the speed in falling asleep may also have been influenced by the lateness of going to bed, which was well into the night of the natural rhythm of sleep (Nicholson 1986a). However, the subjects then slept less restfully during the latter part of the night as the local time of rising was around midday in the home time zone.

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It has also been observed that during the second and third nights after the flight, the ratio of REM to non-REM sleep is raised (Nicholson 1986a). This finding is expected since REM sleep increases when sleep is shifted to later in the natural rhythm of sleep and wakefulness (Nicholson 1984). By the fourth night, a normal sleep pattern was established which indicated that sleep had adapted to the new time zone.

Following a corresponding overnight eastward flight, subjects appeared to sleep better on the first night because the first rest period was delayed by 19 hours (Nicholson 1986a). However, they experienced difficulty in falling asleep and the ratio of REM to non-REM sleep was reduced (Nicholson 1984). Sleep adaption took longer and the subjects still had reduced total sleep time and sleep efficiency by the fifth night (Nicholson 1986a). The slow adaptation is to be expected as the internal clock has a somewhat longer period than the natural day. More acute changes have been observed following eastward flights in the form of isolated sleep paralysis (Snyder 1983). This is the sudden inability to perform voluntary movements occurring at the onset of sleep or upon waking during the night or in the morning. The attacks usually last 10 minutes and end spontaneously through external sensory stimulation. It is usually experienced during REM sleep and events that induce alterations in the parameters of REM sleep such as transmeridian travel may be expected heighten the chances of occurrence of sleep paralysis.

From these observations, it would appear that the immediate effect of a transatlantic journey is determined by the delay to the first rest period and whether the flight is during the day or overnight, with the subsequent disturbance being determined largely by the direction of the flight. In addition to this, consideration must also be given to the influence of splitting the habitual eight hour sleep period into several episodes as may happen when the subject sleeps for some time on board the aircraft. On examining this, it has been found that four hours of sleep taken at the same time each day are generally sufficient to "anchor" circadian rhythms to a 24 hour period, even when the other four hours are taken irregularly (Minors 1992), although how effective the use of anchor sleep is in stabilising circadian rhythms with respect to home time is not known. However, the potential usefulness of anchor sleep is underlined by the fact that consideration has been given to scheduling duty periods for air crew so that there is the possibility of taking anchor sleep during irregular sleep-activity rosters (Graeber 1990a). In addition, recent work has looked at the effect of night-time naps on recovery from fatigue following night work. Matsumoto (1994) looked at two groups of shift workers where one group was able to take a two-hour nap during the night, whilst the other group was unable to nap. Although no significant difference was found when comparing the length of the day sleep of those employees not having a night time nap with the total sleeping time (night time nap plus day sleep) of those having a nap, the daytime sleep of the no-nap group was significantly longer than that of the nap group on both the first and second days after the night shift. Therefore, it may be surmised that naps taken during night-time work can to a certain extent aid recovery from the fatigue caused by that work.

Studies have already been performed in air crew and when examining the duration of sleep periods over a month in long haul pilots, it becomes apparant that short naps of about an hour in duration and sleep periods of around 3-4 hours are not uncommon, with the naps frequently preceding and the short sleeps following long haul flights (Pascoe 1994, Stone 1993,

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Spencer 1991).

In addition, short episodes of sleep are often taken during the 24 hour rest periods between flights and rather than taking a long sleep immediately after the flight, aircrew sometimes split their sleep into two parts. The strategy of limiting sleep early in the rest period assists the individual to obtain adequate sleep before the next flight, thus avoiding undue sleepiness during the duty period. The value of short episodes of sleep taken in anticipation of a prolonged period of work is well established. It has been shown that alertness and performance on many tasks decline overnight, and a 4 hour period of sleep during the evening before a night shift leads to a sustained improvement (Nicholson 1985). On the other hand, very short naps of around 1 hour have a more limited effect on performance, particularly when a significant deterioration has already occurred (Rogers 1989). Nevertheless short periods of sleep may be useful prior to a flight departing in the evening (Nicholson 1986b), or during very long flights when the entire period of wakefulness may be 16 hours or longer (Stone 1993). Furthermore, naps may help aircrew cope with time zone changes, such as after a westward flight when the first sleep period in the new environment is delayed relative to home time (Pascoe 1994).

1.15 THE EFFECT OF AGE ON TRAVEL FATIGUE

Following travel across time zones, the rates of adjustment to new schedules are not the same for every biological rhythm (Desir 1981). The phase relationships of several rhythms may therefore differ from their usual pattern and this may be the cause of symptoms. This fact is important for all travellers, but may be of increased importance for older individuals who are possibly at more risk of impaired adjustment to travel across time zones (Graeber 1982, Rietveld 1984). These age-related factors may be attributed to a diminution in the ability of circadian rhythms to adjust (Graeber 1982, Akerstedt 1981b), an increase in the amplitude of rhythms (Reinberg 1978, Reinberg 1980), more time required to recuperate (Akerstedt 1981b) and more sleep disturbance in older individuals (Graeber 1982). However, there is far from universal agreement that age affects the ability to adjust to schedule shifts (Kerkhof 1985).

To attempt to identify if age is a real factor in this ability, a study was undertaken by Mark (1988) to examine the effect of an acute six-hour phase advance on 8 early middle-aged men (aged 37-52 years) and a second study to compare the effects of a simulated time change where the daily routines were shifted six hours earlier on two groups of young men (aged 18-25 years) and early middle-aged men (aged 37-52 years) (Moline 1992). Important age-related differences in adjustment were found. The middle-aged individuals were noted to have larger increases of waking time during their sleep period and earlier termination of their sleep than young subjects. They also reported larger decreases in alertness and well-being and larger increases in sleepiness, weariness and effort required to perform daily functions. It was hypothesised by Moline (1992) that the symptoms reported by the middle-aged subjects might be due to difficulty maintaining sleep at early times of the circadian day and that their compensatory

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response to sleep deprivation might also be less robust when travelling across time zones.

1.16 OTHER FACTORS AFFECTING TRAVEL FATIGUE

The aircraft environment has significant effects on the feeling of well-being during the flight and consequently has a marked effect on the degree of travel fatigue experienced by passengers.

Cabin Pressurisation

Discomfort as a result of altitude is first felt at approximately 4000 to 7000 feet and therefore cabin pressure is normally maintained at an equivalent of no greater than 6000 feet (McFarland 1975). Whilst this condition is acceptable, it is possible that passenger comfort might be increased and fatigue reduced if the cabin pressure could be held at the equivalent of 3000 - 5000 feet during long haul flights.

The effect of altitude on mental function is often difficult to assess because of the effects of practice on the various performance tests. However, in tests of immediate memory, some impairment has been noted at altitudes as low as 6000 - 8000 feet (McFarland 1969), including some lapses of attention.

Humidity

The low relative humidity encountered on aircraft, caused by drying of the air during heating and compression, is one of the main sources of passenger complaints. The effects are primarily drying of the tear film, and hence irritation of the eyes and of the oronasal membranes. If the relative humidity falls below 15%, the effects become more pronounced, especially in the presence of tobacco smoke (McFarland 1953) and a combination of high temperature, low humidity and reduced pressure appears to produce considerable fatigue in passengers (McFarland 1975).

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Carbon Monoxide

It is well known that carbon monoxide is extremely soluble in blood and reduces its oxygen carrying capacity. In addition, it is also known that the effect of carbon monoxide and altitude are additive (McFarland 1944). The average regular smoker has approximately 4 - 8% carboxyhaemoglobin in his blood which would have a similar physiological effect to him being at a much higher altitude than the cabin pressure of 6000 to 8000 feet resulting in increased fatigue and mental impairment (McFarland 1975).

Alcohol

Alcohol exercises its primary physiological action by depressing oxidation in the cells and the effects of alcohol and altitude are additive. For example, at approximately 10000 - 12000 feet, the alcohol in two or three drinks would have the physiological action of four or five drinks at sea level (McFarland 1953).

Diet

Man is extremely versatile and can change his eating pattern to adjust to a change in the light/dark cycle. However, it may be that for an individual who is habituated to a certain daily meal pattern, circadian de-synchronisation will be disruptive.

Age

There are interesting similarities between the effects of high altitude and age. Indeed, most elderly people require higher levels of illumination when reading and have a diminished ability to remember recent events, both of which also occur to younger individuals at high altitude (McFarland 1963). Both effects are likely to be due to hypoxia as a result of diminished availability or utilisation of oxygen. However, unlike alcohol and carbon monoxide, the effects of high altitude and ageing are not necessarily additive.

Speed of Travel

Intercontinental passengers now have a choice of mode of travel on certain routes and may use either Concorde supersonic transport or conventional subsonic aircraft. Studies have been performed to compare the two aircraft types and on the whole it has been found that passengers travel on Concorde predominantly for business reasons and that they report fewer subjective feelings of jet lag (Richards 1978). This is further borne out by measurements using the Stanford Sleepiness Scale and the Profile of Mood States, which both show significantly less disruption following travel by Concorde (Pergament 1982). The Concorde passengers did suffer from jet lag as measured by a newly created "Jet Lag Questionnaire", but not as severely, nor for as long a period as the subsonic passengers (Pergament 1982).

Examining the overall effects of transmeridian travel in a study of 315 senior executives from 29 British and 20 American companies, 87% reported sleep disturbance following travel. It was found that 50% conducted business negotiations before obtaining a nights sleep, but only 20% felt they were fully fit at the time (Conroy, 1970, Conroy, 1971). It would obviously be advantageous if advice could be given regarding methods for reducing the effects of travel fatigue and providing some guidelines on appropriate rest periods following transmeridian travel.

1.17 PHASE ADVANCE VERSUS PHASE DELAY IN THE ADAPTATION TO TIME ZONE CHANGES

When a zeitgeber advance shift is increased from about six to twelve hours, a range which corresponds to flying eastwards from London to time zones between Bangladesh and New Zealand, the response of the entrained circadian rhythm may change from a phase advance to a phase delay. In addition, whilst the rhythm for one variable may adjust by phase delay, it is possible that other variables may phase advance. For instance, in one study the temperature rhythm of half the subjects adjusted by phase delay through fifteen hours, rather than phase advancing through nine hours, despite the fact that most of the subjects showed a phase advance of their circadian rhythm in corticosteroids (Klein 1980b).

The change of phase delay response to phase advance or vice versa is called an antidromic phase response. On reviewing the literature, antidromic responses have been reported for shifts in a ten hour range from +12 to +6 and from -12 to -8 hours. A critical shift is described as the advanced zeitgeber phase shift at which the response to it changes from phase advance to phase delay. Studies have shown that there is evidence that the greatest jet lag problems are related to shifts near to the critical one (Gundel 1989). To ameliorate consequent severe jet lag it would therefore seem important to avoid such shifts if at all possible.

The problem therefore is that for shifts between +7 and +10 hours, subjects would like to adapt by an advance and have to change their behaviour to guarantee that this happens. It can be done simply in two ways. Firstly, by pre-adaptation preceding the flight. In this case, the subject has to advance his sleep and daily activity pattern on one or more days before the flight. Alternatively, he could incompletely shift his sleep and daily activity pattern

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on the first day in the new time zone, and to subsequently distribute the shift to more than one day. In either case, these manoeuvres would facilitate an advance response and reduce the period required for resynchronisation in the new time zone (Gundel 1989).

1.18 THE EFFECT OF TRAVEL FATIGUE ON AIR CREW

The problem of flight crew fatigue is a major safety concern in all types of flying. In short haul operations, crews are required to fly at night, have repeated early starts and a high number of sectors all producing considerable fatigue. In long haul flying, repeated crossing of multiple time zones and the long duration of flights have their own attendant problems.

The UK Confidential Human Factors Incident Reporting Programme (CHIRP) has been running for more than ten years and like NASA's Aviation Safety Reporting System (ASRS), regularly receives confidential reports from long haul flight crews describing how fatigue and sleep loss have contributed to major operational errors (Green 1987). Approach and landing accidents accounted for 44% of all crew-caused accidents in wide body operations during the period 1977 - 1986 (Graeber 1990b), but the cruise phase is not immune to fatigue-related errors.

Long haul operations suffer a 2.4 times higher rate of accidents than short haul flying and differ in a number of ways which affect fatigue. Long haul aircraft regularly operate closer to their performance limits. Crews get fewer take offs and landings - sometimes only one landing a month. Routes are more "hostile" with poor support facilities like air traffic control, communications, weather forecasts and different regulations. Pilots operate regularly when tired due to time zone changes. They have a high proportion of night flights and are frequently under increased domestic pressures because of long periods away from home. All of these factors can increase fatigue and may play an insidious role in eroding a crew's ability to deal with the challenge of the job. This is particularly important in view of the fact that cockpit human error continues to be the prime factor in about 65% of all aircraft accidents.

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As far as domestic aspects are concerned, whilst home absences may increase the home pressures, it is well recognised that the pilot's spouse acts as a major social support system and someone they can turn to to "get things off their chests" and confide in. In addition, the spouse is a significant factor in the pilot's ability to deal effectively with psycho-social stress. In order to capitalise on this, Singapore Airlines introduced a spouse programme in 1987 as part of their Air Crew Resource Management (ARM) seminars (Karlins 1989). The spouse session, scheduled on the final afternoon and evening of a three day seminar, focused on an examination of the husband-wife relationship in the context of an "airline marriage" and allowed the airline publicly to acknowledge the spousal contribution to safer, more effective flight deck performance. The spouse programme was well received by flight crew and their partners alike. In evaluating the seminar, many participants expressed the belief that their spouses would "understand them better" and be more sensitive and sympathetic to the stresses they faced.

One of the major causes of fatigue is sleep deprivation. In studies examining objective data from Boeing 747 long haul crews, it has been found that, on average, most crew members were able to obtain enough sleep during the layover, either by sleeping efficiently at selected times, or by sleeping less efficiently but staying in bed longer than usual (Graeber 1990b). One very clear result emerged regarding the direction of flight, showing that sleep quality decreased more after eastward than after westward flights.

Another finding in eastward travel was that crew members slept for a considerably shorter duration on the second night than they had on the first night in the new time zone. The reason for this is thought to be that the greater sleep on the first night is due to the effect of the sleep loss experienced by the all-night eastward flight. Once this debt is partially recovered, sleep is more vulnerable to disruption by the desynchronised body clock on the second night. This interaction of sleep debt and circadian rhythmicity also explains why the first night's sleep is often poor in crew members who sleep for more than three or four hours during the morning after arriving from an all night eastward flight.

As a way of putting this principle into practice, Lufthansa has experimented with new crew rotation periods for long haul flights in an effort to reduce recovery periods in cabin and flight crews. The working principle is that if crews are returned to home base quickly, their recovery rates will be minimised because they are not forced to adapt fully to the new time zone. The experiment involved crews flying to Los Angeles or San Francisco from Frankfurt and they were permitted only a 24-hour rest period before working the return flight to Frankfurt. In principle, this should limit their recovery period to just one day, rather than the three days they previously experienced when staying in California for longer (Proctor 1993).

In long haul crews, the one individual factor which strongly affects sleepiness is the age of the crew member. This has been significantly correlated to an increased number of awakenings, a high percentage of light drowsy or restless sleep, a low percentage of deep sleep and lower sleep efficiency and is particularly true for those crew members over fifty years of age (Graeber 1990b).

One of the most revealing findings of Graeber's study came from records of

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crew members napping in their seat during the cruise. The naps usually occurred during the local night, but there were also occurrences during day time flights. The other members of the crew would continue to perform their duties and typically would not say anything. No more than one person was asleep at any one time and no naps lasted more than one hour. However, not all experiences are as reassuring. A quote from a CHIRP report is alarming to say the least:

"The crew had a 40 minute drive in ABC to the airport and then operated as follows: One hour turnaround then a 53 minute flight to XYZ. One hour turnaround followed with a 8.33 hour flight to London Heathrow with 30 minutes at Heathrow making a grand total of 12.33 hours on duty (scheduled) with no delays. Halfway through the flight I awoke to realise I was the only one awake - a sobering thought. I had been asleep at least 30 minutes." (Green 1987).

Reduced alertness and sleepiness on the long haul flight deck results from two different sources:

i) The external circadian desynchronisation arising from duty at a time of day when sleep is the norm, and

ii) The cumulative sleep loss that can develop from the inability to sleep after crossing time zones. Whilst the pilot may obtain his usual amount of sleep during the layover, he may still succumb to the influence of the body clock at the "wrong" time of day, or he may be flying at the "right"' body time, but suffer from some prior sleep loss. Added to this is the fact that there is a biphasic

> sleepiness rhythm, in other words, the tendency to sleep increases markedly every 12 hours with peaks in the early part of the afternoon and often in the early hours of the morning (Richardson 1982).

No discussion of pilot fatigue can be complete without consideration of the Civil Aviation Authority's document CAP 371 - The Avoidance of Fatigue in Aircrews - Guide to Requirements (Civil Aviation Authority 1990). It was recognised in the 1950s that aircrew fatigue may have been a contributory factor in some aircraft accidents. The Bader report was commissioned and the Flight Time Limitation Board convened with the object of regulating the hours worked by aircrews. Restrictions placed on the number of hours worked, developed over the years, have gone a long way towards ensuring that crews are sufficiently rested prior to commencing a flying duty period. CAP 371 was first issued in April 1975 and since then has gone through three editions until the most recent issue published in July 1992. This endeavours to set limits on the allowable duty hours and minimal periods of rest for flight crews and cabin attendants employed by holders of a United Kingdom Air Operators Certificate. British commercial pilots may fly a maximum of 100 hours a month and no more than 900 hours a year. According to the flight time limitations, they must have seven days off in four weeks. In addition, pilots may not fly more than 55 hours a week or 95 hours a fortnight. No more than three consecutive night flights will be allowed and no more than four early starts or late finishes. However, it must be remembered that flying only occupies a proportion of the time spent away from home on a trip. In a study examining transport aircrew workloads (Hartman 1971), the time away on mission was analysed as shown in Table 1.

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Table 1 - Table of component time periods on flight missions

Phase of Mission	% of Time Away
Off Duty	55.5%
Sleep	30.5%
Other, eg shopping, sight-seeing	20.5%
Waiting	4.5%
Mission Flying	27.7%
Pre- and Post-flight Duties	13.1%
Other Work	3.8%

Historically, one of the first to recognise the adverse effects of time zone changes on sleeping was Wiley Post. He determined the effects of altered sleep/wake cycles on his flying efficiency and took steps to adjust them in ways which were beneficial in his global flights in 1931 and 1933 (Mohler 1971, Post 1931).

In the opening of the air routes across the Pacific and Atlantic Oceans during 1937 to 1939, studies were made on operational fatigue in the flight crews of Pan American Airways (McFarland 1953). In the flying boat operations across the Pacific, the overnight layovers on islands en route assisted in the adjustment to the changes in the time zones. Such luxuries are no longer available to the crews of the current long haul jets, such as the Boeing 747-400 where non-stop flights between London and Tokyo are routine and London to Sydney are feasible. As a result, we are now in a situation where not only are the crew subjected to time zone changes, and hence "jet lag", but are also in effect shift workers with its own attendant problems. It is therefore important that a distinction should be made between shiftwork and "jet lag" as they apply to commercial aviation.

Studies of the rotating shiftworker are of particular interest to the aviation industry because many flight crews work rotating shifts or have duty rosters that are shifting in nature. In shiftworkers, and especially those on rotating shifts, the sleep/wake cycle is often desynchronised from the external day/night cycle and from the prevailing social interaction cycle. When the body rhythms begin to adapt to the new zeitgebers, they do so at different rates (Wever 1979). The result is that many rhythms lose their phase relationship with one another, causing internal desynchronisation (Samel 1987).

The aircrews of most major airlines appear to be much like shift workers in terms of their chronic exposure to phase alterations. The bidding system for specific trips on an airline's network is based on seniority and ensures that many of the younger crew members fly less desirable schedules. However, a major difference between the transmeridian traveller and the rotating shift worker is that the traveller experiences acute phase alterations, whereas the worker experiences repeated, chronic phase alterations. Nonetheless, symptoms reported from transmeridian travel are similar to those reported by shift workers and these include fatigue, insomnia, anxiety and other sleep/wake disturbances, gastrointestinal dysfunction and psychosomatic manifestations (Price 1990).

Despite this, there is a major difference between the air traveller crossing time zones and the shift worker in that the latter is faced with conflicting zeitgebers, whereas the former arrives at a destination where the prevailing social and day/night cycles are not conflicting, and indeed are probably relatively similar to the phase relationships at home.

A study by Beh (1991) examined air crew performance following stopovers on long haul flights. They compared Qantas Airways crews on the Sydney-London-Sydney route with crews on the Sydney-San Francisco-Sydney route. The former crews were able to maintain fairly normal sleep cycles and sleep periods, whereas the same was not true for the San Francisco crews. These personnel experienced disruption in sleep scheduling and a reduction in both the quality and quantity of sleep. The study also confirmed the findings from previous work on sleep deprivation which showed that with regard to performance, the accuracy of response in self-paced tasks tends not to be affected although output does (Wilkinson 1965). In other words, the disruption of the sleep to aircrew tends to affect the quantity of work rather than the quality. But more importantly, it showed that the mental performance of aircrew may not have returned to normal levels when crews are required to report for duty following a stopover. This point was particularly true on the San Francisco route where flight scheduling and duty rosters resulted in considerable disturbances of sleep routines, which, in turn, seemed to adversely affect mental performance.

Finally, regardless of the physiological and performance aspects of circadian dysrhythmia, one must also consider the psychological aspects. It is possible to assess jet lag using mood ratings (Bassett 1985). These ratings when applied to cabin crew on the Sydney to Los Angeles route, showed a clear and consistent pattern of increasing fatigue and decreasing efficiency as a result of travel across time zones. The author concluded that the major factor accounting for these changes was circadian dysrhythmia as

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demonstrated by urinary cortisol excretion.

A more recent study on Finnish cabin crew travelling on the Helsinki-Los Angeles-Seattle-Helsinki route (Suvanto 1993a) examined body temperature readings which indicated that the cabin crew's circadian system was in a state of de- and re-synchronisation for an average of more than nine days during which only four days was spent in the United States. It is postulated that if the crew member has twenty similar trips in a year, then the circadian system may be in a state of desynchronisation for 180 days of that year. Indeed, it has been observed previously that the menstrual cycle of female cabin crew is prolonged (Preston 1974) and it is thought that the rapid time zone changes are stressors which delay ovulation. Frequent desynchronisation may therefore go some way to explain the high rate (30-35%) of menstrual disturbances in cabin crew (Preston 1974).

The Finnish study concludes that although the entire de- and re-synchronisation process takes on average more than nine days during and after a round trip of ten time zones, the resynchronisation alone after the return flight lasts more than four days. As far as performance is concerned, the resynchronisation of alertness was found to be more rapid than that of body temperature and visual search. It was therefore reassuring that the scheduled recovery time, which for Finnish cabin crew is five days, seemed on average to be sufficient for the resynchronisation of the circadian rhythms of body temperature, alertness and visual search, as well as the rhythms of melatonin, cortisol and sleep/wake cycle (Suvanto 1993a).

1.19 REST REGIMES FOLLOWING TRANSMERIDIAN FLIGHTS

The traveller's physical and mental state after a long distance flight is generally influenced by:

i) Personal factors, such as emotional and health status, job situation, motivation, age and adaptability

ii) Geographic and environmental factors such as climate, departure and arrival time, geographic translocation and the associated time shifts, altitude and accommodation, and

iii) Operational factors such as duration of flight, flying speed, and number of stops en route.

In 1967, a formula was proposed by the Staff Advisory Committee of the International Civil Aviation Organisation (ICAO) in which four of these factors were used to compute physiological rest periods after long haul flights (Buley 1970). This formula was the sum of functions of flight duration and the number of time zones crossed, weighted accordingly to the local times of departure and arrival in such a way as to include an eastward/westward travel differential.

As it evolved, the equation was:

$$\text{Rest Period} = [\text{Flight Duration (in hours)}]/2 + [\text{Time Zones in Excess of 4}] + C_D + C_A$$

where C_D = Departure time coefficient

C_A = Arrival time coefficient, and the rest period is in tenths of a day

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The departure and arrival coefficients were selected on the basis of the shape of a typical circadian curve for a performance index and on the social pattern (in particular the community sleep period) of the place of departure and arrival (Buley 1970). The final values are shown in Table 2.

Table 2 - Table of Departure and Arrival Coefficients for Rest Period equation (Buley 1970)

Local Time	Dep. Time Coeff.	Arrival Time Coeff
08^{00} - 11^{59}	0	4
12^{00} - 17^{59}	1	2
18^{00} - 21^{59}	3	0
22^{00} - 00^{59}	4	1
01^{00} - 07^{59}	3	3

Following the success of the Buley Formula, subsequent efforts resulted in the development of a new formula which included age and geographical and directional factors, expanded the local departure and arrival time coefficients and even considered relatively small time zone shifts. The formula was then converted into a assembly resembling a circular slide rule, which facilitated easy calculation of the final recommended physiological rest period (Gerathewohl 1974).

1.20 COPING WITH THE EFFECTS OF TRAVEL FATIGUE

As outlined in preceding chapters, the labels "travel fatigue" and "jet lag" have been given to a variety of symptoms that are experienced by individuals when crossing multiple time zones by air. There are two main components to the syndrome:

i) Stress effects that stem from the particular physical and psychological aspects of the flight itself (Carruthers 1976), and

ii) Those effects that are a product of the need to reset the biological clock (Winget 1984).

i) FLIGHT EFFECTS

The effects due to the first component, the flight itself, include malaise, nausea, headache and aching joints. They seldom last more than a few hours after the end of the flight and are a function of the duration of the flight, rather than the number of time zones crossed. Many of these effects may stem from mild dehydration and reduced oxygen uptake during the flight. Counter measures include drinking adequate fluids, avoiding coffee and alcohol and reducing smoking. Fruit juice and decaffeinated beverages are best for restoring any fluid loss. Cramped seating conditions can lead to aches and pains and whenever possible passengers should attempt to walk up and down the aisle to get some exercise. If this is not possible, then exercises whilst seated will help stimulate the circulation (British Airways 1994). Isometric exercises (alternate tensing and relaxation of muscles) or those involving only limited movement (of neck, back, arms and legs for instance) can be performed conveniently within the confines of the seat. Loose comfortable clothing should be worn and tight shoes removed (Monk 1987).

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Psychological stress may be reduced by a number of different coping strategies. The first is to lessen the stress at either end of the flight itself by arranging for the most convenient ground transportation, the most easily handled luggage, and an adequate amount of time for the transfer. Whilst actually on the aeroplane, the extra service of business or first class may help, but, even if budgets do not permit this, then the traveller should indulge in treats (either intellectual or gastronomic), and comforts (such as cushions or a Walkman), such that the flight is made more tolerable. Most importantly, the approach to the journey should be a positive one, with sufficient preparation to feel that one is in control of the situation (Monk 1987).

ii) BIOLOGICAL CLOCK EFFECTS

Other effects stem from the need to reset the biological clock to a new time zone. These are much longer lasting and may continue for a week or more (Klein 1972a). The biological clock cannot adjust instantaneously to the sudden change in routine that results from flights across time zones. Several days are required and whilst the process of adjustment is taking place, there are a number of symptoms which may be experienced. These may include, in decreasing order of frequency:

Fatigue and psychomotor degradation
Insomnia and sleep/wake disturbances
Anxiety or depression
Gastrointestinal dysfunction, and
Other psychophysiological complaints (Rockwell 1975).

The reason for this spectrum of symptoms is that under a constant

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environmental light/dark cycle, physiological and behavioural rhythms maintain a relative synchronisation with each other (internal synchronisation) and with the daily rhythm of sunrise and sunset (external synchronisation). That is, in steady state conditions, they exhibit their peaks and troughs at approximately the same time of day or night, depending on their natural rhythm. If this steady state is disrupted, as may happen with rapid transmeridian air travel, then the physiological and behavioural rhythms are desynchronised and the symptoms of travel fatigue or jet lag result (Comperatore 1990).

The intensity of these signs and symptoms is a function of many factors including the age and experience of the traveller, the total time zone change, the number of stopovers and the direction of travel. The phenomena of internal and external desynchronisation may occur with time zone changes of three hours or more (Rockwell 1975) and whilst the somatic changes may be annoying, they are less critical than the performance and psychological changes. There may appear significant decrements in complex and fine perceptual motor activities which will of course be important in certain occupations. In addition, mood alteration may also be experienced. There appear to be significant increases in depression, hostility and aggression (Rockwell 1975) which may have significant implications for those involved in contract negotiations. It is not easy to identify which individuals are going to suffer most from the effects of travel fatigue, but a recent study has concluded that the traveller's personality is one of the best predictors of circadian rhythm adaptation after transmeridian flights (Suvanto 1993b) although following a long haul flight, many of the symptoms (sleep duration, motivation loss, subjective sleepiness) show an erratic recovery pattern suggesting the interaction of competing processes

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(Monk 1988).

This thesis is particularly concerned with the effects of transmeridian travel on performance, but objective measurements of cognitive performance, vigilance and so forth are sparse and the changes often small (Lewis 1970, Graeber 1980). This has been interpreted as an indication of the insignificance in objective terms of any effect of jet lag on performance. However, one should be cautious about this approach as it is likely that under experimental conditions, most subjects are capable of a significant degree of conscious or subconscious compensation, at least in the short term. It is less certain that this compensation can be sustained in the longer term, but what is clear is that there is a dissociation between the severity of the subjective feelings of disorientation, tiredness and so on, and the degree of objective deficit recorded. Subjects who feel worst, do not necessarily perform worst. Conversely, the biggest deficits may be recorded in individuals who are unaware, or do not report, any subjective symptoms (Redfern 1989).

It must also be remembered that in a similar way to physiological parameters, performance abilities and mood have daily cycles and therefore, after some changes in time zones, the part of the cycle normally coincident with sleep may now be coincident with wakefulness, thereby producing low levels at a time when optimum performance is required. Performance, alertness and mood may therefore suffer simply as a function of rhythm timing and for the first few days after arrival, one should consider the timing of important events and meetings with respect to both destination and home time zones. Examples of particular activities to avoid are:

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i) Driving in the early hours of the morning (home time) as vigilance and concentration will be most impaired (Colquhoun 1971), and

ii) Complex problem-solving in the mid to late evening (home time) as short term memory and verbal reasoning will then be most impaired (Folkard 1975, Folkard 1980).

A useful system is to make a list of all major events in the first few days after arrival using both destination and home time zones in order that meetings and events that may present difficulties may be identified (Monk 1987).

As one would expect, the major factor which determines the time for resynchronisation is the number of time zones crossed during the flight. It is estimated that it takes approximately one day for each time zone crossed to readjust to the new environment although the direction of flight also has a bearing on the time required for resynchronisation. Obviously, flights in the north-south direction have little to do with desynchronisation as no time zones are crossed, but travel eastward or westward do have more significant effects. Experimental work has shown that re-adaptation following a westward flight takes 30 to 50% less time than flights travelling eastwards (Klein 1977). The difference in the intensity of de-synchronisation results from the fact that the natural biological rhythm of the body is approximately 25 hours long, making it easier to adjust to conditions which lengthen the day (Winget 1985). This becomes apparent when flying westward (phase delay) and the subject's day is lengthened as opposed to the shortened day of flying east (phase advance).

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As indicated earlier, other individual factors have a bearing on the time required for resynchronisation. Personality is particularly important in this context and may be broken down into:

i) **Morning versus evening types** - the evening type fares better when travelling in a westerly direction, compared to the morning type, and vice versa in the easterly direction. It has been suggested that this is due to the fact that "evening types" seem not to experience sleep deficiency, and more easily extend the sleep period when sleep onset is shifted to late hours (Ehret 1983).

ii) **Introvert versus extrovert types** - in broad terms the introvert is synonymous with the morning type and the extrovert with the evening type (Loat 1989) and as a result, there is a corresponding difference between the two (Holley 1981). If an individual is the type who exposes himself to outside visual and mental stimuli, in other words, he is an extrovert, then the resultant chemical changes in the brain help to keep him more alert (Ehret 1983). Extroverts have their peaks later in the day and therefore adapt more easily to a phase delay (westward flight) than to a phase advance (eastward flight) (Winget 1985).

iii) **Regimented versus flexible** - some individuals live by the clock and this regimented personality tends to experience less jet lag as they rigidly enforce the new time zone on their habits (Ehret 1983).

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iv) **Stable versus neurotic** - anxious individuals secrete hormones and neurotransmitters that unsettle body rhythms and therefore may delay phase adjustment in the new time zone (Ehret 1983)

As well as personality, age is extremely important and it has been shown that as age increases, there is a shift in the sleep cycle which leads the individual to go to bed and rise at earlier times (Miles 1980). This has a great effect on the introvert, whose rhythm for morning activity will become stronger (Horne 1977), thereby increasing the effect of any circadian dysrhythmia. In addition, there are many other minor factors influencing the time required for resynchronisation and everything from diet plans (Ehret 1983) to hypnotics (Arendt 1982) have been found at one time or another to have some influence.

As indicated, travel fatigue is the result of the particular physical and psychological aspects of international travel (eg making connections at airports, luggage problems, customs checks), the flight itself (dehydration, changes in altitude effect) and those that are the product of the need to reset the biological clock on arrival. For them to be effective, coping strategies must ameliorate both physiological and cognitive aspects associated with travel fatigue.

a) Travel crossing a few time zones only

If an individual is flying to the east and crossing only one or two time zones or flying to the west and crossing three or less time zones, then he is unlikely to suffer from the effects of jet lag. However, there will still be effects due to lost sleep, the stresses of the journey and the need for adjustment to local surroundings, drinking and eating habits (Waterhouse 1990).

If three or four time zones are crossed, then some effects of jet lag may become apparent. The major causative factor is the disturbance of the traveller's sleep/wake cycle and in these circumstances, the passenger should be encouraged to manipulate his sleep/wake cycle before departure. If the subject deliberately desynchronises his rhythm some days before the flight, then his sleep/wake cycle will correspond to the destination's new time zone more rapidly. It is quite easy to preset sleep/wake cycles so that they correspond with the times of the destination, by going to bed either a few hours before or after normal bedtime in the days preceding the flight (Loat 1989). Anchor sleep has been shown to act as a circadian rhythm synchroniser by imposing relatively constant sleep/wake cycles (Minors 1981b). The anchor sleep needs to be at least four hours in length and may be augmented by naps during the day although even if these naps are taken at irregular times during the day, the anchor sleep can still be maintained and act to facilitate the re-adaptation of the passenger's circadian rhythm.

When dealing with a flight over a relatively short distance, there is not a great deal that can be manipulated to produce any substantial effect which would hasten circadian resynchronisation. However, one recommendation is that on boarding the aircraft, the traveller should immediately reset his wristwatch to the new time zone and attempt to follow activities appropriate to the new time. Food may sometimes be of help in this, as mealtimes can act as strong zeitgebers provided the meals are eaten at a regular time. Meal constituents also are known to affect the synchronisation of circadian rhythms and diet plans have been developed which attempt to alleviate the effects of circadian dysrhythmia. These diets consist of pre-flight alternation of light and heavy meals and the alteration of the protein and carbohydrate balance in meals. It is claimed that a high protein breakfast and a low protein/high carbohydrate dinner will facilitate the resynchronisation of circadian rhythms following a phase advance shift by the synthesis of catecholamines from protein and the synthesis of serotonin from carbohydrates (Ehret 1980). In addition, the administration of chronobiotic drugs, for instance caffeine in coffee, is claimed to alter the period of timing of circadian rhythms and these may be used to speed up resynchronisation after a transmeridian flight as they produce a rhythm phase shift in the direction of the time at the destination (Walker 1981).

Following arrival, the most important thing the traveller can do is to become immersed in the society and activity patterns of the destination. Outdoor activities are recommended since daylight assists in the process of adjustment, but social interaction is also an important factor. The study by Klein and Wegmann (1974) demonstrated that an inside/inactive group took 50% more time to resynchronise to local time after a six-hour time zone change. On the whole, it has been found that with shorter journeys, eastbound flights have a greater negative effect on morning performance and westbound flights have a more adverse effect on evening performance (LaDou 1979).

b) Travel crossing several time zones, but only a short visit

If the stay in the new time zone is brief (one or two days), then a substantial adjustment is unlikely. Under these circumstances, it may be a better alternative for the traveller to maintain the home routine. To do this, it is important that meetings are arranged at times coincident with daytime at home and care taken to avoid times coincident with night at home. After a flight to the east, meetings should be scheduled to take place in the latter half of daytime rather than in the morning by local time. After a flight to the west however, meetings should take place in the morning by local time rather than in the latter part of the day. If tiredness ensues, a short nap before an important meeting may be beneficial as long as it ends at least one hour before the meeting to ensure that the individual is fully awake (Waterhouse 1990).

c) Travel crossing several time zones and staying for at least several days

If the traveller is staying longer, then an attempt to promote adjustment of the body to the new time zone may be made. In other words, the passenger should match his lifestyle to that of the new time zone as fully and rapidly as possible. Many of the topics discussed in (a) are again pertinent, but in addition, drugs may be of some benefit (see Sections 1.12 and 1.13). However, there is a marked difference in the effect of westward and eastward travel and each should be discussed separately.

i) Westward travel (Waterhouse 1990, Waterhouse 1993)

A journey westward requires the passenger to delay his body clock. This should be fairly easy to manage and the procedure may be split into:

Before the flight

An attempt should be made to adjust lifestyle to the new time zone in the days immediately before departure. One method is for the traveller to go to bed one or two hours later than normal each night and get up one or two hours later each morning. However, it is rarely useful to try and adjust fully

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to the time zone transition before the journey as this would disrupt lifestyle too much.

During the flight

The passenger should set his watch to destination time as soon as he boards the aircraft. During the flight, an attempt should be made to sleep if it is night time at the destination, or stay awake if it is daytime. However, there are some problems with this system in that the flight schedule is generally arranged in accordance with the time in the departure point.

In addition, during the flight, the passenger may attempt to image events corresponding to the time of day on their watch. This method is known as Synchronised Circadian Phase Change (SCPC) (Jurka 1981) and involves for instance, imagining that when the passenger takes his meal, the meal in question should coincide with the meal that he would have been eating at the time on his watch, regardless of the meal that is actually being consumed such that if the time is 1.00 pm, then it should be considered to be lunchtime, and the meal thought of as lunch.

After the flight

In general passengers should adopt the new local time for all aspects of lifestyle.

Sleep

It is likely that the tendency will be for the individual to wake early and feel ready for sleep in the afternoon and passengers should therefore attempt to sleep in surroundings that are quiet, dark and comfortable.

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Physical activity

Light exercise and brisk walks taken at the individual's accustomed hour by local time will help the adjustment. Natural light may help to speed the resynchronisation and following a four-hour westward flight, the passenger may attempt to delay his body clock by facilitating exposure to natural light between 17^{00} and 23^{00} local time.

Social activity

Social activities are a good way of hastening adjustment to the new time zone providing they do not prevent retiring at the correct time.

Meals and drinks

As an alternative to SCPC, an attempt should be made to ensure meals are of the "correct" type, for instance, breakfast or lunch at the appropriate adjusted times. There is some evidence that high protein foods (fish and meat) and caffeine-containing drinks (tea and coffee) are best taken in the morning and that a light snack rich in carbohydrate (fruit juice and dessert) is best for supper. Alcohol on the whole is a bad nightcap as it both alters the normal sleep cycle and acts as a diuretic therefore causing the passenger to wake to pass urine.

ii) Eastward travel (Waterhouse 1990, Waterhouse 1993)

Following a flight to the east, the body clock is behind the new local time and needs to advance. However, as has been indicated earlier, the body clock tends to "run slow" and therefore takes longer to adapt by phase advance.

In broad terms, a four-hour time zone change westwards may require up to

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three days to adjust whereas a corresponding eastward flight will take up to five days. However, despite this, the general principles and advice are similar to those given for a westward flight.

Before the flight

Once again, an attempt should be made to partially adjust to local time by going to bed one or two hours earlier each night and getting up one or two hours earlier in the morning. This is generally less intrusive on a normal lifestyle than the procedure necessary for westward flight.

During the flight

The advice is generally similar to that given for westbound flights.

After the flight

Again, as with westbound flights, passengers should adopt the new local time for all aspects of lifestyle.

Sleep

As the new local time is ahead of the body clock, the passenger will have difficulty waking up and feeling alert in the morning. If individuals have difficulty getting to sleep at night, then some purposely "miss" their first sleep in the new time zone to ensure that they are tired on the second night although this strategy very much depends on the arrival time of the flight. The converse of this is that if the passenger feels tired when it is time to get up, then they should not stay in bed, but get up, allowing themselves at most a short "lie in".

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Physical and social activities, meals and drinks

The advice is much the same as for westward flights, but on this occasion, following a four-hour eastward flight, the body clock should be advanced by facilitating exposure to natural light between 09^{00} and 15^{00} local time.

Drugs and travel fatigue

For those individuals on regular medication, there will inevitably be some alteration after a time zone transition and change of routine have taken place. Medical advice may be required and this is especially true for insulin-dependent diabetics.

The foregoing are generally accepted broad guidelines for minimising the effect of travel fatigue following transmeridian flights and in general, studies have shown that it takes about one day of recovery for each time zone crossed (Aschoff 1975). The effects may therefore be long-lasting, and, indeed, the same process will happen on the return journey, although there is no evidence that adjustment is any more rapid in the homeward direction than in the outward one (Klein 1972a).

It is difficult to try to give general advice for coping with jet lag and travel fatigue, but in essence (Monk 1987, Postgraduate Medicine 1983):

- The passenger should be well rested before the flight.
- The passenger should change his wristwatch to the destination time on boarding the aircraft.
- The passenger should consider stopovers instead of direct flights when crossing four or more time zones.

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- The passenger should avoid caffeine, alcohol and smoking.
- The passenger should be advised to drink plenty of fluids.
- The passenger should be advised to exercise in his seat and move about the aircraft whenever possible.
- The passenger should be advised to get out into daylight on arrival.
- The passenger should be advised to stay up until normal destination bedtime.
- The passenger may consider staying on home time for short trips, and finally
- The passenger should be advised to allow time for adjustment to the new time zone on return home.

SECTION 2

PSYCHOLOGICAL PERFORMANCE MEASURES

2.1 AN OVERVIEW OF THE NEED FOR PERFORMANCE MEASURES

The fact that transmeridian travel and the resulting desynchronisation can adversely affect performance has been well documented (Klein 1972b, Klein 1977, Klein 1974, Klein 1980b). In these studies, Klein used both pilot and student populations as subjects, with tests designed for occupational realism, namely cockpit simulations. After crossing 6 time zones in an eastbound direction, 24-hour mean performance levels decreased 3-4 % compared to pre-flight levels. Performance decrements in both simple tasks such as reaction time, and the complex sensory motor skills required to operate flight simulators, were more severe following easterly flights than westerly flights.

Indeed, following westward flights, the decrements observed in simulator performance and psychomotor performance were not significant (Klein 1976). However, following eastward flights of 6-9 time zones, significant decreases in efficiency, lasting from 1- 5 days post-flight, were found in flight simulator performance, psychomotor performance and hand-eye coordination, see Table 3.

Table 3 - Table of % performance decrement following eastward flights of 6-9 time zones

Task	% Decrement	Reference
Flight Simulator Performance	9%	Klein (1976)
Psychomotor Performance	3.5%	Klein (1976)
Hand-eye coordination	8%	Levine (1972)

A variety of performance tasks and indices of psycho-physiological complaints have been evaluated in military personnel following studies of eastward transatlantic travel through 6 time zones (Wright 1983). After the flights, 50% of personnel reported fatigue and sleep difficulty and 40% reported subjective weakness. The symptoms diminished significantly by the fifth post-flight day although deterioration persisted in a number of physical parameters such as sprint times and elbow flexor strength. In addition, other studies have shown that logical reasoning may also be reduced by up to 15% (Graeber 1982).

Further studies have included north/south flights in addition to trans-meridian flights to determine whether fatigue or stress induced by the flight itself contributes to the performance decrement (Hauty 1966). It has been found that the effects of north/south flights are insignificant compared to those arising from transmeridian flight.

Performance decrements in ground based phase shift studies have been found to be greater following phase advances (simulated eastward flight) than following phase delays (simulated westward flights). Wever (1980) found significant impairment in psychomotor performance following 6-hour phase advances, but not in phase delays of the light/dark cycle. Significant deterioration in vigilance, calculation proficiency and mood was observed in subjects whose sleep/wake period was advanced 2 - 4 hours (Taub 1974). Female subjects advanced by 8 hours exhibited a 17 - 38% deterioration in short term memory, reaction time and visual search performance (Preston 1978). Student pilots whose sleep/wake period was advanced 2-5 hours exhibited sleep impairment, a 35% increase in flight performance errors, and a 14% decrement in letter cancellation performance (Yurchenko 1981).

Thus it is quite apparent that the crossing of time zones and the resulting

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phase shift of performance and physiological rhythms often results in significant performance decrements. The aetiology of these decrements is almost certainly the end result of many factors including sleep disturbance, workload, psychological and dietary factors, and specific individual physiological characteristics, all of which contribute to the phenomenon of desynchronisation (Winget 1984).

2.2 PROBLEMS OF PERFORMANCE MEASUREMENT

Although conceptually the idea of measuring performance is relatively simple, in practice, a whole series of difficulties present themselves which make objective measurement difficult. For instance, measuring whether a given individual has performed a task well is straightforward when there are measurable skills, such as those required by an airline pilot, but for persons involved in areas such as marketing and contract negotiation, it is very much more difficult to detect any performance decrement. It must also be borne in mind that any changes that are measured may be due to differences in the type of task, the workload or the external circumstances, rather than changes to performance by the individual himself.

As a result of this, it may be that it is better to consider the problem from a different angle and to examine only poor performance, as assessed by accidents and errors. However, this can be just as difficult in the case of the marketing executive and a distinction needs to be drawn between manifest errors and performance that is generally substandard. In addition, with regard to jet lag it is erroneous to attribute a higher error rate or poorer performance wholly to the effects of the body clock as many other factors are also involved. Therefore, in order to improve the reliability of performance data a number of conditions should ideally be imposed on a study (Waterhouse 1990):

i) The same individuals should be investigated at a number of different times during the day and on a number of different trips

ii) The tasks being assessed should always be of the same type and level of difficulty, and

iii) The task should be "self paced", in other words, the subject, not the task should decide the rate.

Other factors will obviously have an influence on performance although in the type of study being proposed by the author, their control is not possible:

i) Tests should be done after the same time interval from waking each day as there are known circadian cycles which will influence results

ii) External factors such as lighting, heating and noise, should be kept constant, and

iii) No alcohol should be consumed.

Of these three conditions, the latter two are beyond the investigators control on an overseas business trip. There is some capacity for standardisation of condition i), but in view of the fact that the subjects will be undertaking the author's study in addition to their normal work, it is only possible to specify periods and not specific times during which the performance tests should be undertaken.

As has already been discussed, it is very difficult to assess work performance in certain occupations. However, it is possible to break all jobs down into simple components and then to make assessments of these individually. There are a whole range of potential components, and these are outlined below, but inevitably, in any undertaking, it is impossible to examine them all and therefore only those of particular interest in this study will be discussed.

2.2

The Sensory Component

Information has to be taken into the brain by the organs of sensation. The eyes are the principle route in humans, but touch, hearing, taste and smell are all important in certain occupational groups (eg. carpenter, piano tuner, tea taster and perfumier respectively).

The Central Component

The information received needs to be processed by the brain which may include reasoning, thinking or memory.

The Motor Component

Once processed, the information needs to be executed and this may involve writing, pressing a button or something more complex such as driving.

Short Term Memory and Vigilance

Short term memory facilitates the retention of information long enough for it to be acted upon, for instance, memorising a telephone number after looking it up before dialling it. This type of information is often of transient value and unnecessary to convert into the long term memory store.

Finally, vigilance is the component by which changes are detected in our environment such as new traffic conditions or a faulty item on a conveyor belt.

2.3 REQUIREMENTS FOR AN INSTRUMENT TO UNDERTAKE PERFORMANCE MEASUREMENT

Over the years, attempts have been made to measure performance by devising a variety of artificial tasks (Folkard 1985c). These have advantages over "real" tasks in that they enable standardised tests to be performed throughout the 24 hours of the day and can be assessed objectively. Furthermore, the type of test can be tailored to requirements. Such tests can therefore vary the amount of short term memory, speed of reaction, vigilance or data handling that is required and can concentrate on sensory or motor tasks or be made more complex should this be required.

In this study a "process approach" (Larsen 1989) has been used, developed by Totterdell and Folkard (1992), which involves collecting time-series data for each individual. This is desirable as there is no satisfactory alternative to repeated measures of the variable under consideration within and across a number of cycles. The properties of the underlying rhythm include its periodicity, phase and amplitude and research methods for the investigation of periodic variations in psychological performance, particularly variations that are of a diurnal nature, are considered to be part of the study of chronopsychology.

The Study of Affect

Studies of affect have included investigations of daily stress and mood (Bolger 1989, Delongis 1988) and have normally involved the use of self-report, paper-based diaries.

Typically, subjects are requested to carry their diaries as they go about their normal routines and to record their subjective responses. Technology may also be employed in the form of programmable watches, but usually only to signal the participant to complete the diary and not to record responses (Csikszentmihalyi 1987). More recently however, programmable hand held computers have been used to record, as well as signal the responses (Totterdell 1992, Barr-Taylor 1990).

The Study of Cognitive Performance

Most of the chronopsychological studies of cognitive performance have been investigations of circadian and time of day effects (Folkard 1990a). In addition to laboratory-based studies, there have been a number of field studies in which on-the-job measures of performance have been used and a few in which standard laboratory measures have been applied (Monk 1985). In the latter studies, researchers have normally relied on paper and pencil tests, either administered infrequently by the investigators (Wojtczak-Jaroszowa 1978) or by the participants themselves, using stop watches to time their own responses (Folkard 1977b). The reliability of data obtained by the latter method is therefore questionable.

Performance tests on personal computers are likely to be more reliable (Rosa 1988), but are difficult to administer in field studies even when all the subjects are located on one site, and impossible to administer in a study of this type where transcontinental travel is involved. Even if personal computers are feasible for certain studies, they are disruptive to the subjects work routine and virtually rule out obtaining measures during the workers' leisure time. The hand held computer developed by Totterdell and Folkard and used in this study has the potential of overcoming these disadvantages.

Necessary Requirements for Study Instrument

Considering the above factors, an instrument that can be used in field

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studies for the collection of repeated measures of both affect and cognitive performance, should fulfil the following requirements (Totterdell 1992):

i) It must be portable and the subject must be able to carry the instrument at all times

ii) It should be inexpensive so that each participant may be given a machine for the duration of the trip

iii) It should record the date and the time at which the participant responds

iv) It should accurately record elapsed time which is essential for cognitive performance measures such as reaction time

v) It should have sufficient display size to allow presentation of tasks

vi) It should have sufficient memory for program and data storage, and

vii) It should allow downloading of data to a personal computer for subsequent analysis.

Totterdell and Folkard (1992) have developed a suite of programs for a programmable hand held computer which satisfy the above requirements and, since 1990, the programs have been used successfully in a number of field and laboratory studies which have enabled the technique to be validated.

2.4 TASK PROGRAMS FOR PERFORMANCE MEASUREMENT

As outlined in Section 2.3, it is necessary to assess both affect and cognitive performance. With regard to affect, the two most commonly used methods utilise adjective check lists (Nowlis 1960, Nowlis 1965) or visual analogue rating scales. In the latter the subject makes a mark across a horizontal line at a position which indicates how he feels with respect to the particular factor under scrutiny. This technique has been advocated by Aitken and others (Aitken 1965, Zealley 1969, Aitken 1970). Since each subject places himself appropriately along the line, the problem of different scales for each category and failure to reflect subtleties of feeling may be overcome, at least in part (Aitken 1969). This principle has been employed by Totterdell and Folkard in their programmable hand held computer (Totterdell 1992) and a number of 20-point subjective rating scales for alertness, mood and task load have been programmed (Hart 1988). In addition to rating scales, the computer may also be used as a diary to document sleep and work pattern together with alcohol consumption, and this potential has also been utilised by Totterdell and Folkard (1992).

Reaction time has been shown to be sensitive to many factors, including fatigue and sleep loss (Wilkinson 1964) and time of day (Gillooly 1990). Reaction time can be assessed in a number of ways and early attempts to develop a portable system utilised an audio cassette recorder (Dinges 1985), which has been successfully applied to airline pilots and demonstrated diminished performance at the end of long haul flights (Pierce 1993). The serial choice reaction time test employed by Totterdell and Folkard and executed on the programmable hand held computer has the advantage of versatility in the machine and a test that has been shown to be sensitive to a range of stresses (Broadbent 1963). As might be expected, other tests of cognitive performance are available, but in this study the intention has been

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to concentrate on memory. To do this effectively, a task is necessary which differentiates between factors that affect response processes and those that affect central memory scanning processes. This requirement is satisfactorily fulfilled by the Sternberg Memory Search test (Sternberg 1969) which is similar to the Advisory Group for Aerospace Research and Development (1989) implementation of the task and in the light of this, has been employed previously by Totterdell and Folkard (1992) and developed for use in the programmable hand held computer.

2.5 THE PSION® PROGRAMMABLE HAND HELD COMPUTER

The programmable hand held computer program developed by Totterdell and Folkard (1992) utilises rating scales, serial choice reaction time and memory search tasks as methods for assessing both affect and cognitive performance. The system has been employed in both field and laboratory studies and in a recent study (Folkard 1991), the Psion® Organiser was used to collect data from 3 participants every 3 hours while they were awake over a 26-day period of which the last 15 days were spent in a temporal isolation unit where they were on a 30-hour sleep/wake schedule.

The results showed that the practice effect for a 4-choice serial reaction time test persisted in 1 participant throughout the course of the study and therefore suggests that practice effects are unlikely to be completely eliminated and should be taken into account during analysis.

More detailed sensitivity analysis of the results shows quite clearly the presence of 25- hour, 30-hour and possibly 21-hour performance rhythms for the four choice serial reaction time tests.

Totterdell and Folkard have found the Psion hand held computer to be a valuable and practical instrument for repeated measures of cognitive performance and self reported affect. It allows the investigator to collect data at all times of day and night in all locations without direct intervention or excessive disruption objectively recording when a task is completed and obtaining objective measurements of response time.

Participants in their field studies responded favourably on the use of the Psion. Only 2 out of 40 participants reported that they had not enjoyed working with it and only 1 participant reported difficulty in using the

2.5

instrument (Totterdell 1992).

Compliance was generally satisfactory, although it was as low as 50.2% in one study requiring 2-hourly tests. However, given that the study lasted for 28 days and the tasks took approximately 6 minutes to complete, the participants were expected to give up 22 hours of their time to the study with no incentive, financial or otherwise. However, in general, compliance was higher during work hours although leisure time readings dropped off considerably during the latter half of the study (Totterdell 1992).

The major limitation of using the Psion is that the investigator has no control or knowledge of the conditions under which the test is completed. Ambient conditions such as light and noise are likely to vary considerably and interruptions and social inhibitory factors may also be important. Hand and finger positioning and the eye-to-display distance are also likely to change.

Another problem, common to all measuring instruments is that the Psion may interfere with the participants' daily life and hence alter the factors being measured. However, the extent of the problem is difficult to assess short of looking for discrepancies between results obtained with different instruments.

In summary, programs for the Psion Organiser, developed by Totterdell and Folkard, have enabled the author to undertake a study of travel fatigue involving participants making long haul transmeridian flights without the need for observers or bulky recording equipment.

SECTION 3

METHOD

3.1 BACKGROUND TO THE STUDY

From the foregoing sections, it is clear that the effect of travel fatigue is influenced by many factors including:

- i) Pre-flight activities causing stress and tiredness
- ii) In-flight activities, such as the timing of meals and sleep and the artificial environment of the aircraft cabin with its pressurisation and low relative humidity, and
- iii) Post-flight activities, where the pattern of sleep and light exposure will influence the rate of circadian readjustment

It is also apparent that there are many characteristics in the travellers themselves that have a bearing on the impact of travel fatigue. In particular, the age of the individual, whether they use hypnotics to aid sleep, or are smokers, whether they drink alcohol and of course their personality type, in terms of introversion and extroversion.

A considerable amount of work has been done over the years looking at the effect of time zone shifts on physiological and performance parameters. Aside from air crew, most of these studies have used volunteer subjects travelling solely for the purposes of the study. Their aims have been to look at the effect of time zone shifts on specific parameters and, as a result, as many confounding factors as possible have been controlled. This methodology is useful from the scientific point of view, but from the occupational health standpoint ignores the influences of other equally important factors on the overall impact of travel fatigue. This study has therefore been developed to look at subjects both before and after long haul flights without controlling confounding factors, in an attempt to evaluate the overall effect of travel fatigue on human performance.

3.1

In the airline industry, there are two quite separate groups of frequent travellers. The first group are the flight and cabin crew operating the routes. They have specific requirements for optimum performance during the flight, but after the journey are able to rest and relax as required to prepare for their next sector. However, British Airways, like any other company whose markets extend across the world, has a large number of employees travelling on business. These personnel have a very different requirement for optimum performance, and in their case, need to function at their best after the flight. It is this second group of frequent travellers who are the subject of this thesis.

The project was conceived and commenced whilst the author was employed by the United Kingdom Atomic Energy Authority (UKAEA) and subsequently completed at British Airways. The aim was to examine the effect of transmeridian travel on regular long haul passengers and was divided into two phases: Phase 1, a questionnaire-based Traveller Profile Study and Phase 2, a Performance Measurement Study. As required, the study protocol (see Appendix I) was submitted, together with copies of the proposed questionnaires for approval by the UKAEA Ethical Committee.

Although a few of the subjects in Phase 1 and all of those in Phase 2 were known to the author, their data was anonymised before analysis by the allocation of unique Subject Identification Numbers. On review, the UKAEA Ethical Committee were satisfied with the proposed study and approved the protocol accordingly without need for revision.

As indicated above, the project was undertaken while the author was in full-time employment as a Senior Registrar in Occupational Medicine with AEA

3.1

Technology (United Kingdom Atomic Energy Authority) and British Airways and whilst both organisations provided enthusiatic support for the study, it must be taken into account that some restraints have had to be placed on methodology and data analysis as a result of commercial pressures.

3.2 PHASE 1 - TRAVELLER PROFILE STUDY - OVERVIEW

Phase 1 of the study examines in more detail the hypothesis that extroverts (night people) and introverts (morning people) adapt at different rates to phase advances and phase delays (Horne 1977, Winget 1985) and therefore may suffer the effects of travel fatigue to a greater extent following a transmeridian flight in one direction compared with the other. Within the limitations imposed by a working population, the study also examines the fact that as age increases, there is a shift in the sleep cycle which leads to the older individual going to bed and rising earlier (Miles 1980). This in turn reduces their adaptability to a change in the temporal structure of the environment (Hauty 1965) and thus may make them more susceptible to the effects of travel fatigue.

In addition to the two principal aims outlined above, other factors were also examined including the sex of the individual, how experienced they were in long haul travel, whether they took any medication to combat travel fatigue, the nature of their normal sleep pattern, whether they were smokers, and whether they drank alcohol or caffeine containing beverages on board the aircraft. Efforts were also made to examine whether any of these factors correlate with the severity of travel fatigue suffered by the individual.

From an occupational health viewpoint, the object of the study is to examine whether a questionnaire-based personality profile is capable of identifying those individuals likely to suffer significant effects of travel fatigue in advance of their first transmeridian flight, and, if this is the case, which are the most sensitive predictors of susceptibility. This would then enable occupational health advice to be directed to those most at risk in order to minimise the disruption caused by their journey such that they may effectively carry out their business both overseas and following their return.

3.3 PHASE 1 - TRAVELLER PROFILE STUDY - METHOD

The Phase 1 questionnaire (see Appendix II) was administered to 100 subjects, all of whom had made at least one transmeridian flight crossing five time zones or more in the preceding six months. The subjects were all volunteers and recruited though the Occupational Health Department of AEA Technology (United Kingdom Atomic Energy Authority) and British Airways Health Services. Twenty of the volunteers were also participating in Phase 2 of the study (the Performance Measurement Phase) and their documents were clearly identified as such. The questionnaires from the remaining eighty subjects were completed anonymously if the individual so wished and, following submission, each subject was allocated a unique sequential identification number commencing with Subject Identification Number 1 for those subjects participating in both Phases 1 and 2 of the study and with Subject Identification Number 100 for those subjects participating only in Phase 1.

Recruitment was achieved by a variety of methods:

a) By direct approach to employees attending the Occupational Health Department of AEA Technology for travel vaccinations

b) By direct approach to employees of AEA Technology and British Airways known to be regular long haul travellers, and

c) By response to an advertisement in the AEA Technology Newspaper "Culham/Harwell News" (see Appendix III), or through E-Mail to the network of companies whose occupational health service was provided by AEA Technology .

3.3

Traveller Profile Questionnaire

A copy of the questionnaire will be found in Appendix II. The document consists of separate sections each dealing with specific areas of information.

Section 1. General information

Contains details of the date of completion of the questionnaire together with the subject's age and sex.

Section 2. Travel Information

This section enquires about the subject's experience of long haul flights, the direction of travel in which they suffer most travel fatigue, the nature of their symptoms, whether they take medication or use any other strategies to reduce the effects of travel fatigue (see Appendix VII), whether they smoke and which beverages they normally consume in flight.

Section 3. Personality Type

As determined by two standard psychological questionnaires.

Section 3.1 (a) - (r)

These questions make up the Circadian Type Inventory (CTI). The full CTI consists of thirty items, contains two sub-scales (Vigourousness and Flexibility) and is based on the Circadian Type Questionnaire (Folkard 1979b, Kaliterna 1988, Costa 1989). Both questionnaires have been developed by Professor S. Folkard formerly of the Medical Research Council (MRC)/Economic and Social Research Council (ESRC) Social and Applied Psychology Unit in Sheffield, and further refined in order to reduce the required number of questions. Factor analysis of the responses of 1532 nurses and midwives allowed twelve items to be dropped resulting in ten

3.3

questions examining Languidness/Vigourousness and eight questions examining Flexibility/Rigidity of sleeping habits (Barton).

Subjects were provided with instructions for completing the questionnaire in order to standardise the method of response as far as possible and each question required a response of "almost never", "seldom", "sometimes", "usually", or "almost always", scoring 1, 2, 3, 4 or 5 respectively. The scores for the ten questions examining Languidness/Vigourousness and the eight questions examining Flexibility/Rigidity were added up and for both factors, high scores indicated a tendency towards the first of the two descriptions for the dimension, that is, Languid or Flexible types.

The questions related to each dimension were:

Languidness	a, d, f, g, j, k, m, o, q, r
Flexibility	b, c, e, h, i, l, n, p

Section 3.2 (a) - (m)

These questions form the Composite Morningness Questionnaire (CMQ) which was developed by Smith (1989) in response to the poor reported psychometric properties associated with existing published "Morningness" questionnaires (Horne 1976, Torsvall 1980). It was constructed by factor analysing the items of the two scales together (twenty-six items) and identifying three reliable factors, relating to morning activities, morning affect and "Eveningness", and selecting out those which load most highly on each of the factors. Through further examination of the items, thirteen were finally selected, nine from Horne and Ostberg (1976) and four from Torsvall and Akerstedt (1980). The psychometric properties of the composite scale appeared to be superior to previous measures, although the main limitation seemed to be the inclusion of numeric statements which made some comparisons difficult.

The questionnaire requires tick responses to each question and subjects are requested to choose the response which best describes them and not to cross check their answers.

For each question, a score was assigned to the response on a scale of 1 to 4 or 5, e.g. **Question (c)**

"In normal circumstances how easy do you find getting up in the morning?".

Score:	Not at all easy	1
	Slightly easy	2
	Fairly easy	3
	Very easy	4

The scoring system was complicated by the fact that the responses to some questions attracted a score of ascending value (i.e. 1, 2, 3, 4, 5 as above) whilst others attracted a score of descending value (i.e. 5, 4, 3, 2, 1). For ease of data entry by the author, the scores for all questions were recorded in ascending format (as shown above for Question (c)). During the analysis phase, ascending and descending scores were then separated and the necessary calculations made to provide an overall score.

The questions attracting scores of **Ascending Value (A)** were:

c, d, e, k

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whilst the questions attracting scores of **Descending Value (D)** were:

a, b, f, g, h, i, j, l, m.

The final score was then calculated using the equation:

$$(\Sigma A) + (48 - \Sigma D)$$

To facilitate interpretation of the results, the final scores were grouped into one of three categories:

Overall Score	22 and less	-	Evening type
	23 - 43	-	Intermediate type
	44 and above	-	Morning type

Section 4. Sleep Pattern

Details the subject's normal sleep pattern. This was done independently of the personality questionnaire so that the individual could enter sleep times in free text without the constraints of a "tick box" response.

Section 5. Comments

Subjects are invited to add any additional comments they may have on their experiences or on the questionnaire.

Section 6. Follow Up Study

Finally subjects are invited to volunteer for Phase 2 of the study should they wish.

3.3

The results obtained for all 100 subjects were then analysed as a group. However, the twenty individuals who were also participating in the Phase 2 of the study had further analyses undertaken in the light of their involvement in the Psion phase.

Data handling

All responses to the questionnaires were encoded onto computer disk using ASCII format. Final scores for the Circadian Type Inventory (CTI) and the Composite Morningness Questionnaire (CMQ) were calculated and the scores used along with the individual's subjective assessments in data analysis.

Notification of Results

All subjects were informed of the procedure for obtaining the results of the study at the time of their recruitment. As most of the subjects in Phase 1 were not known personally to the author, they were advised to contact the department through which they were recruited, namely, the Occupational Health Department at AEA Technology or British Airways Health Services during the Summer of 1995 at which time a written summary of the findings was available.

3.4 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - OVERVIEW

This phase of the study examined the effect of transmeridian flights crossing five time zones or more on the affect, well-being and cognitive performance of regular long haul travellers as measured by serial choice reaction time and memory search tasks.

Additional data were also obtained on sleep patterns and alcohol consumption to assist in quantifying any performance effects and no attempt was made to control confounding factors such as alcohol consumption, smoking, sleep or medication.

From the occupational health viewpoint, the rationale for this approach was to enable a more realistic appraisal to be made of the overall impact of long haul travel, complete with its attendant stresses and confounders, such that appropriate advice may be given to management and individuals regarding the planning and scheduling of overseas trips in order that any detrimental effects can be minimised and performance maximised both before and after the trip.

3.5 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - METHOD

Twenty volunteers were recruited through the Occupational Health Department of AEA Technology (United Kingdom Atomic Energy Authority) and British Airways Health Services. The subjects were requested to participate in the study whilst undertaking five transmeridian round trips each crossing five time zones or more and were encouraged to volunteer only if they were confident they would complete five trips by the end of the data collection phase in Winter 1994/95.

Data collection commenced in March 1993 and subjects were recruited as volunteers or by direct approach from the author. A total of 27 subjects were involved in this phase of the study, with 7 being excluded during the course of data collection. The reasons for their exclusion are detailed in Section 4.3 Phase 2 - Performance Measurement Study - Study Subjects. The principal limiting factor to recruitment was the certainty with which the subject was likely to make five transmeridian round trips during the data collection phase. As a result, it was not possible to confine recruitment to employees of AEA Technology (the author's employer up to April 1994) or British Airways (the author's employer since April 1994) and three subjects were recruited from other organisations, one from a US-based company with a British subsidiary whose occupational health service was provided by AEA Technology, and two others from the University of Oxford.

In outline, each of the twenty subjects was required to undertake performance tests using a pre-programmed Psion® Organiser for a specified period before departure, after arrival overseas, before returning to the United Kingdom and following their return. In addition to the performance tests, the Psion was used to document information on the subject's sleep pattern and

3.5

alcohol consumption and to obtain subjective rating responses at various times during the day. As well as using the Psion, subjects were also required to complete questionnaires outlining their travel arrangements together with other pertinent details regarding their journeys.

3.6 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - TRAVEL QUESTIONNAIRES

Two questionnaires were developed, one for the outward journey and a second for the return journey. Examples of these will be found in Appendices IVa and IVb.

OUTWARD JOURNEY QUESTIONNAIRE (Appendix IVa)

The introductory section required the subject to record his/her name, date of birth, business department and telephone number.

The principal aim of the questionnaire was to record travel details and the subject was therefore requested to complete the document at the time of travel specifying the date, destination and route, the times of their flights including any delays encountered, class of travel, whether they were in a smoking or non-smoking seat and details of their most recent overseas trip.

Enquiries were made as to whether the subject was at work or at home before leaving for the airport. In addition, they were asked to assess their journey to the airport and check-in on a scale of 1 to 5 ranging from "relaxed/no problems" (score 1), to "crowded/other problems" (score 5).

Questions were also asked about the flight itself, in particular, the types of drink consumed and extent of sleep onboard the aircraft. Finally, enquiries were made about luggage and transfer from the airport to the final destination.

RETURN JOURNEY QUESTIONNAIRE (Appendix IVb)

This questionnaire was identical to the previous document, but in addition contained a general section where subjects were asked to rate their mental abilities on the trip, the climate of their destination, the influence of the climate and cultural differences of the country on their mental abilities and any changes in their tobacco consumption. The ratings were made on five point scales similar to those already encountered elsewhere.

All subjects participating in this part of the study had also completed the questionnaire in Phase 1 (Traveller Profile Study) and this enabled some comparisons to be made between information obtained from both parts of the study.

3.7 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - ENROLMENT

At the commencement of the study, the author was provided with a list of names of regular long haul business travellers by the Travel Department of AEA Technology (United Kingdom Atomic Energy Authority). Each potential subject was then approached directly and their possible involvement in the study discussed.

A very high rate of successful recruitment was achieved by this method. During the author's employment with AEA Technology a total of 25 individuals were approached and of these 24 were recruited. At British Airways a further 3 individuals were approached, all of whom were recruited. A single individual declined to be involved in the study as he did not feel the project had any personal relevance to him. The reasons for the withdrawal of the remaining 7 subjects during the course of the study are outlined in Section 4.3 Phase 2 - Performance Measurement Study - Study Subjects.

3.8 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - PSION® ORGANISER

The hand held computer used in this study was the Psion® Organiser II Model LZ which is advertised as an electronic personal organiser. The Psion weighs 250 gms without batteries and its dimensions with the protective case closed are 142 x 78 x 29mm. The LZ model used in this study was fitted with a 64k datapak for the programme and a further 64k datapak for the data files. The machine has a 4 line by 20 character LCD screen together with an alphanumeric keyboard. The Psion has its own programming language, OPL, and programmes can be developed either on the Organiser itself or by using the Organiser Developer Software on a personal computer and then down loading to the Psion. The fifteen machines used in the study were on loan from the Medical Research Council (MRC) where Totterdell (1992) had developed and validated the programs necessary to enable the Psion to be used to measure affect, well-being and cognitive performance in the field without the direct intervention of the investigator. Additional task programs were specifically developed for this study to enable the necessary subjective rating scales applicable to travel fatigue to be incorporated. All programming and data retrieval was carried out at the Medical Research Council (MRC)/ Economic and Social Research Council (ESRC) Social and Applied Psychology Unit in Sheffield with data being returned to the author in ASCII format on standard 3½" computer discs.

The Psion contains a built in clock and calendar which was set to Greenwich Mean Time (GMT) and used for date and time stamping events. Elapsed time was measured by the Psion with an increment every 50 milliseconds. This therefore set the upper limit on accuracy for a single reaction time measurement.

3.8

As previously mentioned, the user programmes were developed in conjunction with Peter Totterdell at the MRC / ESRC Social and Applied Psychology Unit in Sheffield. They were designed to run within a program framework, thus protecting the user from the other functions of the Psion and improving data security. An escape route was provided to allow the investigator to stop the programme. Only through this escape route or by removing and replacing the battery could the subject access the recorded data.

3.9 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - STUDY TIMETABLE

Following recruitment, each volunteer was allocated a unique Subject Identification Number to be used whenever they entered data into the Psion Organiser. At the outset, they also had a briefing session with the author at which time the use and mode of operation of the Psion was explained in detail. All subjects received a comprehensive instruction leaflet (Appendix V) together with a short summary document (Appendix VI).

In order to obtain base-line performance measurements on home time and to eliminate the practice effect whilst overseas, subjects were asked to commence using the Psion Organiser 7 days before departure on their first long haul trip. All subjects were undertaking this study in addition to their normal daily work, and in order to maximise compliance it was considered necessary to limit the test sequences to three performance tasks daily. The subjects were requested not to undertake the tests during their outward or return flights.

The timing of the tasks on each of the test days was selected for two reasons. Firstly, three TEST sequences were used as the minimum number required to demonstrate innate circadian rhyhmicity with optimum compliance. Secondly, the time periods specified for completion of the tasks were selected after discussion with the business travellers themselves taking into account their likely work and entertainment schedules to further maximise compliance. These optimum time periods appeared to be:-

- on rising in the morning
- during the lunch time period
- at the end of the working day, but before any evening engagements, and
- before retiring

It was therefore decided that the final TEST sequence should be performed in the early evening at the end of the working day, in order that the results would not be affected by any alcohol which may be consumed during the evening engagements.

In summary therefore, on each of the test days, subjects were required to perform the following tasks:-

On rising	STARTDAY diary	(Sleep Diary)
	TEST sequence	(Performance tasks)
Lunchtime (12-2pm)	TEST sequence	(Performance tasks)
Before evening meal (6-8pm)	TEST sequence	(Performance tasks)
Before retiring	ENDDAY diary	(Daily Diary)

In addition, subjects were required to complete the NAP diary should they take a nap at any time during the day.

The test days were designated as:-

3.9

7 days before departure on their **first** trip followed by 7 days after their arrival overseas, then

1 day before their return followed by 7 days after their arrival back in their home country.

For all **subsequent** trips they were required to use the Psion Organiser for :-

1 day before departure followed by 7 days after their arrival overseas, then

1 day before their return followed by 7 days after their arrival back in their home country.

However, if any of the trips were less than 7 days in length, then the subjects were requested to use the Psion during their entire time overseas.

3.10 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - USE OF THE PSION ORGANISER

Whenever the Psion Organiser was turned on, the user was first prompted for their Subject Identification Number. They were then presented with a menu of options:

QUIT	TEST
STARTDAY	ENDDAY
NAP	

Each of these options will be considered in more detail in the succeeding sections. It should be emphasised that at the outset the programs were developed as a set of modules, one for each task, in order to simplify the addition of new tasks and to enable Totterdell's original programs developed for shift workers to be modified with reasonable ease to accommodate the requirements of a study examining the effects of travel fatigue.

3.11 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - TASK PROGRAMMES - TEST

Whenever the TEST option was selected, the subject was taken through a number of tasks including subjective rating scales recorded under the file name MOOD and tests of cognitive performance recorded under the file names SRT and PROBE. These ran consecutively, although some exit points were provided between tasks should the user have insufficient time to continue. However, once the user had selected the option or entered a response, there was no means of back tracking.

Rating Scales

There were 20 point subjective rating scales for:

Alertness
Cheerfulness
Calmness

based on the NASA Task Load Index (Hart 1988) utilising a bipolar rating scale.

\- ______________ +
*

To complete a scale, the subject was instructed to move the cursor, shown above as an asterisk, up onto the horizontal line, and then to place it in the desired position along the line, finally pressing the 'EXE' key to indicate that they were satisfied that the chosen position reflected their subjective rating of the parameter required. The data were recorded together with the date and time of completion under the file name MOOD *user id* e.g. MOOD01. The file contents (in order of fields) were:

1 - indicates MOOD file completed as part of TEST sequence

2 - indicates MOOD file completed as part of ENDDAY diary

Alertness

Cheerfulness

Calmness

Serial Choice Reaction Time

Previous studies had shown that reaction time is sensitive to many factors including fatigue and sleep loss (Wilkinson 1964) and time of day (Gillooly 1990). Reaction time may be assessed in a number of ways, but for this study, the Serial Choice Reaction Time test was employed as this has been shown to be sensitive to a range of stresses (Broadbent 1963).

When performing the Serial Reaction Choice Time test on the Psion Organiser, an asterisk symbol appears on the display in 1 of 4 positions. These correspond to the relative positioning of the M, T, W and R keys on the Psion keyboard

```
*                       *
           •                   DISPLAY
     *           *
M                       R      KEYBOARD
     T           W
```

3.11

Following the appearance of the asterisk on the screen, the subject was required to press the corresponding key as quickly and accurately as possible. The next stimulus was then presented immediately.

Subjects were instructed to use the index and the middle fingers of the left hand for the T and M keys respectively and the index and middle fingers of the right hand for the W and R keys respectively. There was a fixation point in the middle of the display which the subject was asked to gaze at between stimuli. Trials in which the subject failed to respond within a set amount of time (1 second) were excluded from the reaction time and, although accurately measured, were not repeated. These trials were termed "Gaps" and the percentage of "Gaps" recorded.

The task sequence consisted of 2 blocks of 80 stimuli. Each set of 8 trials within a block of 80 had 2 stimuli in each of the 4 positions, but apart from this constraint, the order was random. Data were recorded for each block. This caused a short interruption of approximately 1 second between blocks. The Psion's 50 millisecond limit on the resolution of timings meant that a single reaction time measure was not reliable and hence the reaction times were averaged over blocks. The following data were recorded in the data-pak under the file name SRT *user id* e.g. SRT01:

date and time of completion
number of blocks (1 or 2)
number of trials (80)
threshold setting (1 second)
mean response time for the left hand in 100th of a second
mean response time for the left hand - correct responses

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mean response time for the left hand - incorrect responses

% trials left hand incorrect

% trials left hand above threshold

mean response time for the right hand in 100th of a second

mean response time for the right hand - correct responses

mean response time for the right hand - incorrect responses

% trials right hand incorrect

% trials right hand above threshold

Memory Search Task

This task was based on that of Sternberg (1969) and was intended to differentiate between factors that affect response processes and those that affect central memory scanning processes.

The subject was required to memorise a set of 7 letters that appeared simultaneously across the display screen. Once committed to memory, the subject pressed a key indicating that the set had been memorised. A series of 40 letters then appeared, one at a time in the middle of the display. The subject was required to press "T" if the letter was in the memorised set and "F" if it was not.

The memory set letters were randomly selected from the alphabet without consecutive repetition, without vowels and without the response key letters "T" and "F". Each of the remaining letters had an equal chance of being or not being in the memory set. If the subject failed to respond to a letter within 5 seconds, the result was ignored, the fail count incremented and the next letter displayed. However, the original was not replaced. The following data

3.11

were recorded in the datapak under the file name PROBE *user id* e.g. PROBE01:

date and time of completion

size of list (7)

number of lists (1)

number of letters per list (40)

presentation time of list in seconds

number of true positives

mean response time for true positives in 100ths of a second

number of false negatives

mean response time for false negatives in 100ths of a second

number of true negatives

mean response time for true negatives in 100ths of a second

number of false positives

mean response time for false positives in 100ths of a second

number of trials in which subject failed to respond

3.12 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - TASK PROGRAMMES - STARTDAY

In order to obtain a measure of the their sleep pattern, subjects were required to complete the STARTDAY diary on rising each morning. These data were recorded, together with the date and time of completion, under the file name SLEEP *user id* e.g. SLEEP01 in response to the following questions:

I went to bed at (hours : minutes)
I started trying to sleep at (hours : minutes)
It took me ? minutes to fall asleep (minutes)
I awoke ? times (0 / 1 / 2 / 3 etc.)
I lost ? minutes sleep (minutes)
I finally awoke at (hours : minutes)
Did you wake naturally (yes / no)
I got up at (hours : minutes)
Quality of sleep (20 point bipolar rating scale)

3.13 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - TASK PROGRAMMES - ENDDAY

In order to obtain some information on affect, well-being and alcohol consumption, subjects were required to complete the ENDDAY diary before retiring each night. The data, apart from responses to the questions relating to Alertness, Cheerfulness and Calmness which were recorded under the file name MOOD (see Section 3.11), were recorded together with the date and time of completion under the file name DAILY *user id* e.g. DAILY01 in response to the following questions:

Think about today and rate your overall :

Alertness	(20 point bipolar rating scale)
Cheerfulness	(20 point bipolar rating scale)
Calmness	(20 point bipolar rating scale)
Effectiveness	(20 point unipolar rating scale)

How much did you experience the following:

Mental demand	(20 point unipolar rating scale)
Time pressure	(20 point unipolar rating scale)
Disorientation	(20 point unipolar rating scale)
Appetite disturbance	(20 point unipolar rating scale)
Physical Tiredness	(20 point unipolar rating scale)
Other symptoms	(20 point unipolar rating scale)

to be specified by the subject

How many units of alcohol have you consumed today:

Your answer	(units)
Were you working today	(Yes / No)

3.13

The unipolar scales differed slightly from those previously encountered and appeared as:-

o ______________ ++
*

To complete a scale, the subject was instructed to move the cursor, shown above as an asterisk, up onto and along the horizontal line, finally pressing the 'EXE' key to indicate that they were satisfied that the position reflected their subjective rating of the parameter required.

3.14 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - TASK PROGRAMMES - NAP

In addition to their main sleep, some individuals chose to nap during the day. If this was the case, the subject was required to complete the NAP diary to ensure that their overall sleep pattern was recorded. The data were recorded together with the time and date of completion under the file name NAP *user id* e.g. NAP01 in response to the following questions:

My nap started at (hours : minutes)

My nap finished at (hours : minutes)

3.15 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - DATA HANDLING

The modular approach was also maintained in the data files, with each task module creating and updating its own file. Whenever a task was executed, a new record was created in the file. The first field in every record was a time stamp of the current date, hour, minute and second based on GMT. As previously outlined the file name indicated the task and Subject Identification Number.

Following the return of the Psion at the end of the subject's trip, the data pak was sent to Peter Totterdell at the MRC / ESRC Social and Applied Psychology Unit in Sheffield for downloading onto a 3½" computer disc. Simultaneously, information from the outward and return journey questionnaires was encoded by the author into ASCII format and stored on a second 3½" computer disc to enable all subsequent data handling to be performed by computer.

All time entries recorded by the Psion were based on GMT and so adjustments were necessary for British Summer Time (if applicable) and the time zone shift for the journey being considered. Following entry of the appropriate time shift, the correction was performed by computer in order to minimise the potential sources of human error. The subsequent procedures necessary in data preparation are outlined in Section 4.4 Phase 2 - Performance Measurement Study - Data Preparation.

3.16 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - NOTIFICATION OF RESULTS

All subjects were advised at recruitment that they would be personally informed of the results of the study as soon as they were available early in 1996.

As arranged, this notification was in writing, with an invitation to discuss matters in more detail with the author should the subject so wish.

SECTION 4

RESULTS

4.1 PHASE 1 - TRAVELLER PROFILE STUDY - RESULTS

A total of 100 Traveller Profile Questionnaires (see Appendix II) were collected between April 1993 and November 1994, 20 of which were completed by subjects also enrolled in Phase 2 of the study. All subjects had undertaken a longhaul trip (crossing at least 5 time zones) within the preceding 6 months. The respondents consisted of 33 females with an age range of 19 to 61 years (mean 39.3 years, standard deviation 11.7 years) and 67 males with an age range of 25 to 64 years (mean 40.1 years, standard deviation 9.2 years). Overall the population age range was 19 to 64 years with a mean of 39.8 years and standard deviation of 10.1 years.

Five individuals had completed only 1 long haul trip before taking part in the study, however, 52 subjects were experienced long haul travellers, having all completed more than 10 trips previously. Most subjects (44) made on average only 1 long haul trip per year, although significant numbers made more frequent journeys with 16 individuals undertaking more than 5 trips per year over the preceding 5 years. The spread of response for enjoyment based on a 5 point rating scale from 1 (actively dislike) to 5 (actively like) was almost symmetrical with an arithmetic mean of 3.09.

Central to this part of the study was an invitation for the subjects to rate their perception of the severity of travel fatigue, firstly with respect to the direction of travel (Table 4, Question 2.5), although, as expected, a significant number of subjects had no experience of long haul travel in a north/south direction, and secondly, with respect to specific symptoms (Table 5, Question 2.6).

The results obtained are as follows:-

4.1

Table 4 - Table of perceived severity of travel fatigue with respect to direction of travel.

Question 2.5

Direction of travel	No. of subjects	Mean response (Scale 1 - 5)	Standard Deviation
East	97	3.22	0.97
West	100	2.86	1.18
North	58	2.19	0.96
South	62	2.21	0.98

Table 5 - Table of perceived severity of specific symptoms of travel fatigue.

Question 2.6

Symptom of travel fatigue	No. of subjects	Mean response (Scale 1 - 5)	Standard Deviation
a) Sleep	100	3.47	1.34
b) Appetite	99	2.22	1.31
c) Tiredness	100	3.58	1.10
d) Reduced			
Alertness	100	3.13	1.15
e) Other	15	3.60	0.74

The symptoms grouped under the heading 'Other' in Table 5 include migraine, nausea, bowel disturbances and thirst with bowel disturbance being the most common complaint (N = 6).

Subjects were asked whether they took any medication or engaged in any activities during or after the flight to reduce the effects of travel fatigue. Of the subjects, 52 responded in the affirmative for activities during the flight and 55 for activities after the flight. The principle types of medication used were travel sickness preparations (N = 5) or benzodiazepines (N = 8) but far and away the commonest activity was to adopt the new time zone immediately on boarding the aircraft and to establish a sleep pattern according to the new time zone immediately on arrival (see Appendix VII).

With respect to the remaining questions, only 10 respondents were smokers. Enquiries were made about drinking onboard the aircraft, and 88 drank caffeine containing beverages, 97 soft drinks and 79 alcoholic beverages.

Personality Type

For each individual, 3 personality scores were obtained:

i) a score representing Languidness / Vigorousness (L/V),

ii) a score representing Flexibility / Rigidity (F/R), and

iii) a score representing Eveningness / Morningness (E/M)

The results were as follows:

Table 6 - Table of personality scores in subject population

Score type	Number	Minimum Score	Maximum Score	Mean Score	Standard deviation
L/V	100	10	42	29.01	6.52
F/R	100	12	37	23.19	5.42
E/M	100	18	52	39.08	7.04

In addition to the formal personality questionnaires, enquires were also made about sleep pattern and napping. Respondents indicated that their natural sleep requirement varied from 4 to 10 hours per night with a mean of 7.47 hours with a standard deviation of 0.95 hours. The majority chose to go to bed between 22^{00} and 23^{00} local time, although the range extended from 21^{00} to 01^{00}. Correspondingly, most subjects chose to rise between 07^{00}

4.1

and 08^{00} local time, although again, there was an extensive range from 03^{30} to 10^{30}. Finally, 13 subjects admitted to napping on occasions.

4.2 PHASE 1 - TRAVELLER PROFILE STUDY - DATA INTERPRETATION

Before examining whether personality type enables the response to fatigue and symptoms to be predicted, the effect of direction of travel, sex, age, alcohol and naps on the questionnaire responses was separately examined to determine if these variables needed to be included in further detailed analyses of the data.

Many of the assessments used a 5-point rating scale with results being presented in terms of a mean score and any inter-comparisons between groups employing the non-parametric Wilcoxon Sum of Ranks test. Correlations between various measures utilised the Spearman Rank Correlation Coefficient.

Direction of Travel

Table 7 examines in more detail the effect of direction of travel on the perceived severity of travel fatigue. The raw results for travel in an easterly (E), westerly (W), northerly (N) and southerly (S) direction have already been presented in Table 4. On general inspection of the table, it would appear that easterly travel results in a greater degree of travel fatigue than journeys in a westerly or north/south direction. An attempt has therefore been made in Table 7 to quantify this difference, using an average of the perceived severity of travel fatigue in the north/south direction as a base-line. An examination was then made of the difference between this and the scores obtained for easterly and westerly travel respectively. The pair-wise difference in the latter was then tested under the null hypothesis of no difference.

4.2

Table 7 - Comparison of perceived severity of travel fatigue according to direction of travel

Question 2.5 ; 58 Subjects

Direction	Mean	Standard Deviation
Mean (N+S)	2.22	0.96
Mean [(N+S)-W] = W'	-0.72	1.08
Mean [(N+S)-E] = E'	-1.09	1.28
Δ E'W'	-0.38	1.57

From Tables 4 and 7, although the data appears to suggest that travel fatigue is worse following transmeridian journeys in an easterly direction, analysis of the pair-wise difference indicates that the difference is not statistically significant (standard error of the mean = 0.206 ; t = 1.85 ; Prob > 5%).

Sex

Tables 8 and 9 represent a comparison of data between males and females using the Wilcoxon Sum of Ranks test. The test statistic, normalised variate and probability that a more extreme value could have been observed under the null hypothesis of no difference are listed.

There is no indication of any difference of overall perception of fatigue between the sexes, see Table 8.

4.2

Table 8 - Comparison of perceived severity of travel fatigue with respect to direction of travel between males and females

Question 2.5

Direction of travel	Test Statistic S	Standardised Normal Statistic Z	Probability >|Z|
East	1386	-1.46	0.1452
West	1646	-0.15	0.8790
North	567.5	-0.38	0.7057
South	643.0	0.20	0.8437

However, male respondents tended to record that their appetite and mental alertness were more affected by travel fatigue than females, see Table 9.

Table 9 - Comparison of perceived severity of specific symptoms of travel fatigue between males and females

Question 2.6

Symptoms of travel fatigue	Test Statistic S	Standardised Normal Statistic Z	Probability >|Z|
a) Sleep	1569.5	-0.73	0.4664
b) Appetite	1249.5	-2.76	0.0059 *
c) Tiredness	1542.5	-0.94	0.3480
d) Reduced Alertness	1324.5	-2.13	0.0334 *

However, this may simply be based on greater experience as males were found to have made more long haul trips and to have travelled more frequently over the preceding 5 years compared with females, see Table 10.

4.2

Table 10 - Comparison of frequency of long haul trips between males and females

Parameters	Test Statistic S	Standardised Normal Statistic Z	Probability >|Z|
Total No. of trips	1405	-2.11	0.0347
No. of trips / yr	1227.5	-3.39	0.0007

In view of this finding, further analysis was undertaken to identify if there was any difference between experienced and inexperienced long haul travellers in their perception of travel fatigue.

Experience of Longhaul Travel

The 100 subjects were divided into two groups based on their previous experience of long haul travel. The experienced group had undertaken at least 10 long haul trips in the past and comprised 52 subjects, whilst the inexperienced group had undertaken less than 10 long haul trips and totalled 48 subjects. The results obtained are given in Table 11.

Table 11 - Comparison of perceived severity of travel fatigue between experienced and inexperienced travellers

	Exp. No.	Inexp. No.	Test Statistic S	Standardised Normal Statistic Z	Probability >|Z|
Q 2.5 E	52	45	2302.0	0.73	0.4653
Q 2.5 W	52	48	2556.0	0.94	0.3461
Q 2.5 N	35	23	780.0	1.68	0.0921
Q 2.5 S	36	26	961.5	2.12	0.0339
Q 2.6 a)	52	48	2477.0	0.37	0.7092
Q 2.6 b)	52	47	2374.5	0.18	0.8595
Q 2.6 c)	52	48	2614.0	1.36	0.1753
Q 2.6 d)	52	47	2450.5	0.72	0.4687

4.2

The only apparent difference between the two populations is for travel in a northerly or southerly direction where it appears that the perception of travel fatigue for these journeys is less in the more experienced traveller.

Population Sub Group - Subjects Enrolled in Phase 2

Phase 2 of the study, the Performance Measurement Phase, comprises 20 subjects undertaking a number of long haul trips. However, before embarking on detailed analyses of their results, it is important to confirm that they are representative of the whole subject population and are not a highly selected sub-group.

Table 12 represents comparisons between Psion users and the remainder of the subject population using the same comparative statistical method as above.

Table 12 - Comparison of perceived severity of travel fatigue between those subjects enrolled in Phase 2 of the study and the remainder of the subject population

	Psion User No	Non Psion User No	Test Statistic S	Standardised Normal Statistic Z	Probability >|Z|
Q 2.5 E	20	77	908.5	-0.66	0.5078
Q 2.5 W	20	80	866.5	-1.28	0.2007
Q 2.5 N	15	43	396.0	-0.86	0.3914
Q 2.5 S	15	47	399.5	-1.25	0.2120
Q 2.6 a)	20	80	990.0	-0.17	0.8626
Q 2.6 b)	20	79	1056.5	0.51	0.6075
Q 2.6 c)	20	80	1039.0	0.25	0.7990
Q 2.6 d)	20	79	1106.5	0.96	0.3395

4.2

On the basis of these results, there is no evidence to indicate that there is any difference in this context between the Psion users and the remaining subject population.

Personality Type

Table 13 gives a final comparison of males and females based on their personality scores calculated from the questionnaire. It can be seen that there are no apparent differences between the sexes with regard to these measures.

Table 13 - Comparison of personality scores between males and females in subject population

Score type	Test Statistic S	Standardised Normal Statistic Z	Probability >|Z|
L/V	1805	1.01	0.3108
F/R	1513	-1.12	0.2611
E/M	1552	-0.84	0.4026

Age

The respondents' age range was 19 - 64 years (mean 39.8 years, standard deviation 10.1 years). Table 14 presents data for the effect of age on their answers to Questions 2.5 and 2.6 in the Traveller Profile Questionnaire, their personality scores and enjoyment ratings for long haul trips in the form of the Spearman Rank Correlation Coefficients, the probability that the null hypothesis of zero correlation is rejected, and the number of respondents in each category.

4.2

Table 14 - Spearman Rank Correlation Coefficients, probability and number of respondents providing answers for perceived severity of travel fatigue and personality scores compared with age

	AGE
Q 2.5 East	0.119 0.244 97
Q 2.5 West	-0.059 0.557 100
Q 2.5 North	-0.195 0.142 58
Q 2.5 South	-0.273 0.032 * 62
Q 2.6 a) Sleep	0.120 0.233 100
Q 2.6 b) Appetite	0.144 0.154 99
Q 2.6 c) Tiredness	-0.077 0.447 100
Q 2.6 d) Alertness	-0.026 0.798 99
L/V Score	-0.289 0.004 * 100
F/R Score	-0.009 0.928 100
E/M Score	0.241 0.016 * 100
Enjoy Trips	-0.138 0.170 100

4.2

There are a limited number of correlations worthy of note but it can be seen that as age increases, the Languidness/Vigorousness score decreases (P <0.01), and the Eveningness/Morningness score increases (P <0.05). That is, as age increases, individuals tend towards the vigorous end of the Languidness/Vigorousness spectrum and have increasing characteristics of morning types.

Alcohol

In response to the question 'Do you drink alcohol on board the aircraft', 79 individuals answered in the affirmative. The subject population was therefore separated into drinkers and non-drinkers and their responses to Questions 2.5 and 2.6 regarding their perception of travel fatigue examined separately.

The null hypothesis was that the consumption of alcohol does not affect the response to the fatigue questions. Table 15 shows data for the population split between those that do and those that do not consume alcohol.

Table 15 - Comparison of the perceived severity of travel fatigue between subjects consuming alcohol in flight with those not consuming alcohol in flight

	Consumed Alcohol			Not Consumed Alcohol		
	N	Mean	Standard Deviation	N	Mean	Standard Deviation
Q 2.5 E	77	3.17	0.91	20	3.40	1.19
Q 2.5 W	79	2.84	1.15	21	2.95	1.32
Q 2.5 N	44	2.09	0.88	14	2.50	1.16
Q 2.5 S	48	2.06	0.86	14	2.71	1.20
Q 2.6 a)	79	3.53	1.33	21	3.24	1.41
Q 2.6 b)	78	2.28	1.34	21	2.00	1.18
Q 2.6 c)	79	3.53	1.07	21	3.76	1.22
Q 2.6 d)	79	3.04	1.09	20	3.50	1.32
Q 2.6 e)	11	3.36	0.67	4	4.25	0.50

4.2

Table 16 shows the significance levels associated with the Wilcoxon Sum of Ranks test for the same questions.

Table 16 - Significance levels for the Wilcoxon Sum of Ranks test for the perceived severity of travel fatigue in drinkers and non-drinkers

	Wilcoxon Pr > |Z|
Q 2.5 E	0.3462
Q 2.5 W	0.7988
Q 2.5 N	0.2566
Q 2.5 S	0.0514 *
Q 2.6 a)	0.3859
Q 2.6 b)	0.4254
Q 2.6 c)	0.3547
Q 2.6 d)	0.1117
Q 2.6 e)	0.0428 *

Only two comparisons approached nominal statistical significance when contrasting the two populations:

i) Those individuals travelling south (Question 2.5S), have a tendency to rate the severity of travel fatigue higher if they do not drink alcohol than if they consume alcohol. This was nominally significant at the 5% level.

ii) Those individuals reporting additional symptoms of travel fatigue (Question 2.6 e), (e.g. headache, nausea etc.)), seemed to be greater in the drinking group, but this is based on only 11 drinkers and 4 non-drinkers.

4.2

Naps

Only 13 respondents admitted to napping and broadly showed the same response to questions rating fatigue as those who did not nap except for the question relating to reduced mental alertness. In this respect, those who did nap perceived reduced mental alertness to be a greater problem than those who did not nap.

The mean length of time required for sleep amongst those who did and did not nap was very similar at 7.47 hours (standard deviation 0.97 hours).

Personality Type

Table 17 shows the Spearman Rank Correlation coefficients, the probability that the null hypothesis of zero correlation is rejected and the number of respondents for the fatigue and personality measures, to examine whether there is any association between the subjective rating scales derived from Questions 2.5 and 2.6 in the Traveller Profile Questionnaire and the personality scores.

The results infer that the Languidness/Vigorousness score is negatively correlated with both the Flexibility/Rigidity and Eveningness/Morningness scores, not strongly (see the scatter diagrams, Figures 1 and 2), but sufficient to indicate that as the Languidness/Vigorousness score increases, the Flexibility/Rigidity and Eveningness/Morningness scores tend to decrease, that is, the more languid the individual, then the more likely they are to be rigid in their sleeping habits and tend towards being evening types, see Table 17.

Figure 1 Plot of Languidness/Vigorousness score versus Flexibility/Rigidity score obtained from responses to questions in the Circadian Type Inventory

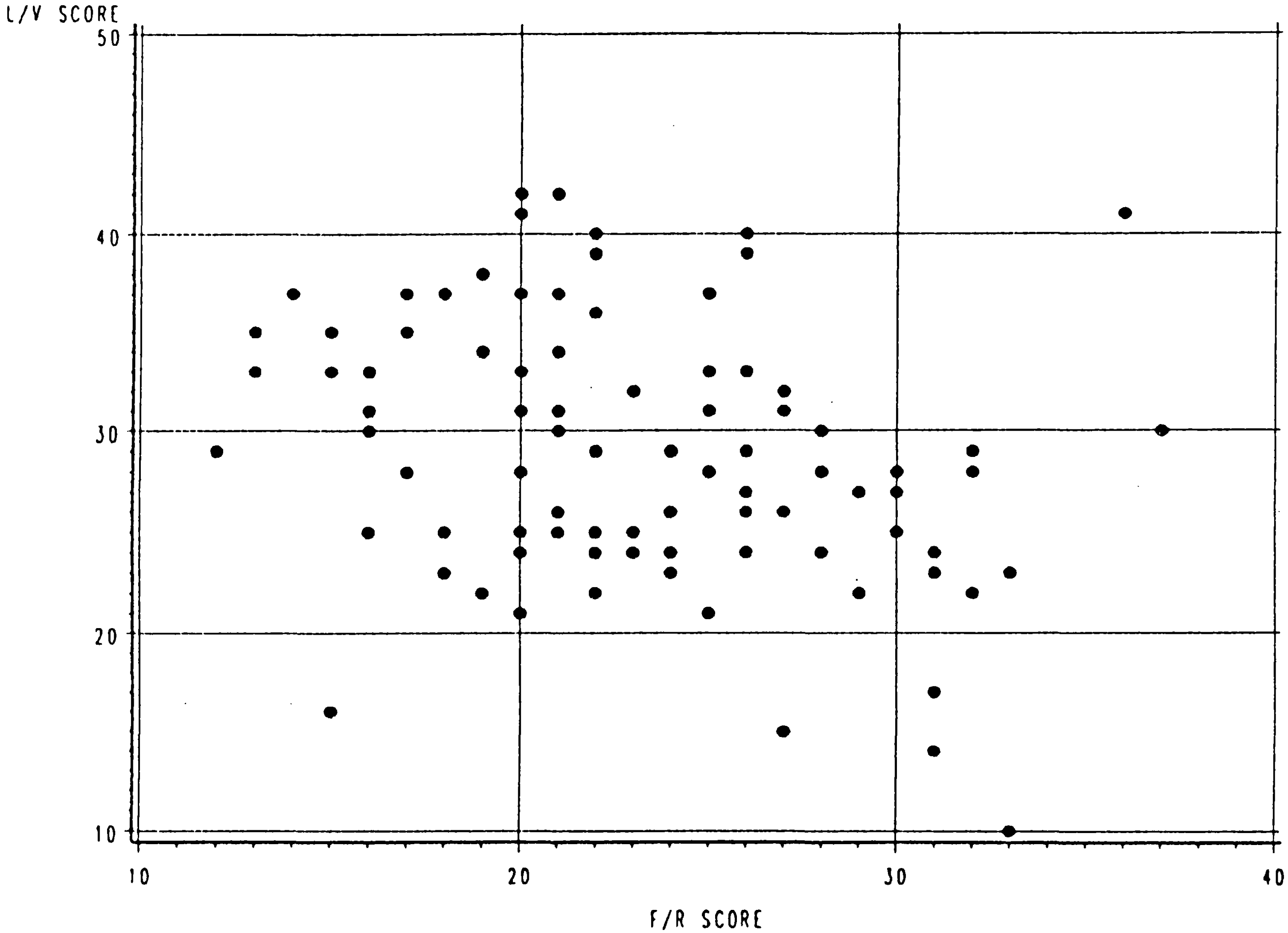
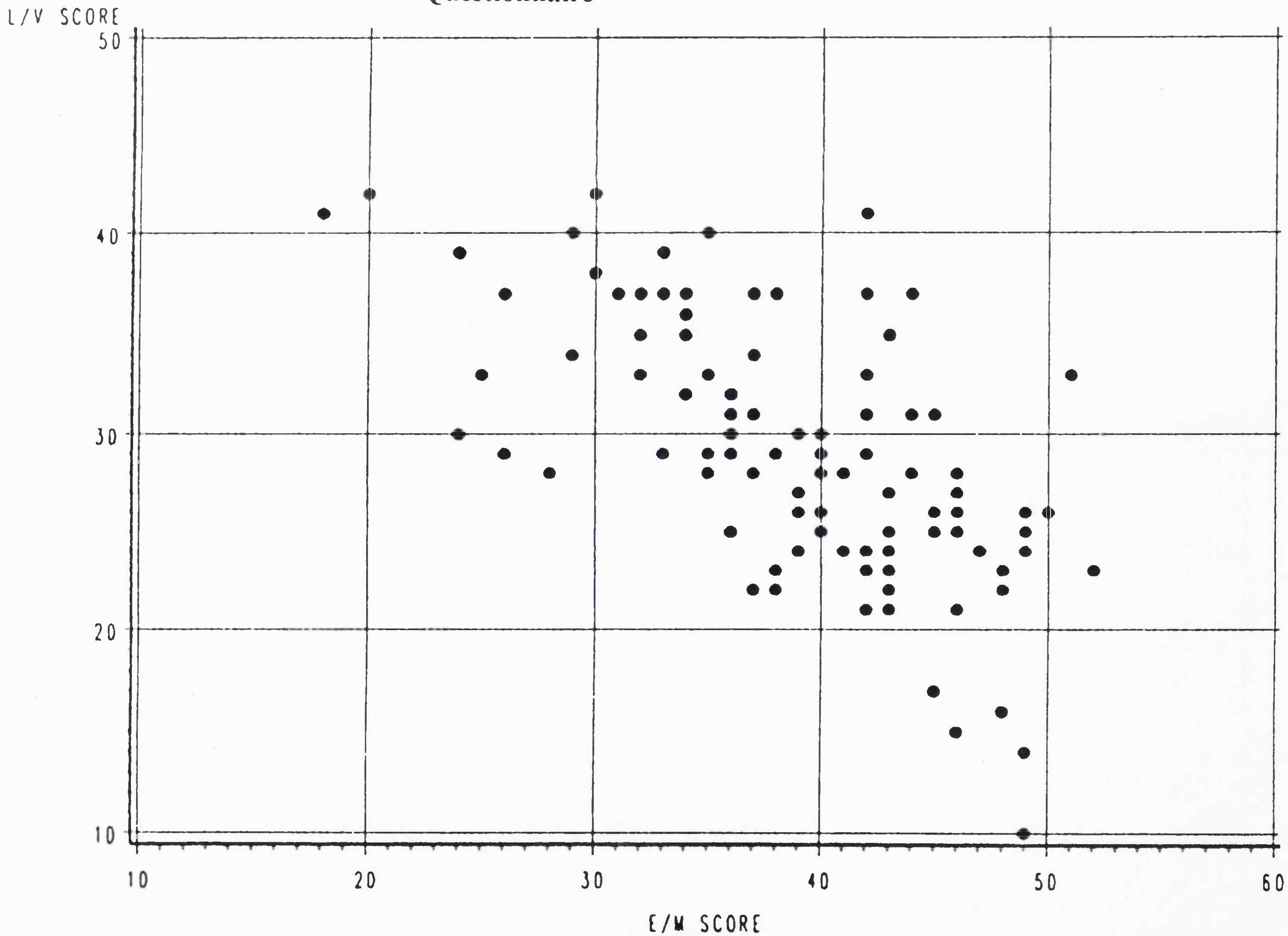


Figure 2 Plot of Languidness/Vigorousness score versus Eveningness/Morningness score obtained from responses to questions in the Circadian Type Inventory and Composite Morningness Questionnaire



4.2

With one exception, there is no evidence to indicate that the Languidness/Vigorousness, Flexibility/Rigidity or Eveningness/Morningness scales assist in identifying those individuals who suffer from the effects of travel fatigue. In all but one case, the correlation coefficients are extremely small and the hypothesis that they differ from zero firmly rejected.

The only exception is a slight negative correlation between the Flexibility/Rigidity score and the symptom of reduced mental alertness whereby as the Flexibility/Rigidity score decreases, the perceived level of reduced mental alertness increases, although not to a degree capable of predictive use, see Table 17.

Table 17 - Spearman Rank Correlation Coefficients, probability and the number of respondents for intercorrelations of perceived severity of travel fatigue and personality scores

	Q 2.5 East	Q 2.5 West	Q 2.5 North	Q 2.5 South	Q 2.6 (a) Sleep	Q 2.6 (b) Appetite	Q 2.6 (c) Tiredness	Q 2.6 (d) Alertness	L/V Score	F/R Score	E/M Score
Q 2.5 East	1.0 97	-.055 .59 97	.130 .33 58	.173 .19 60	.271 .007 * 97	.341 .0007 * 96	.270 .0075 * 97	.322 .0011 * 99	.009 .926 97	.003 .975 97	.116 .257 97
Q 2.5 West		1.0 100	.522 .0001 * 58	.470 .0001 * 62	.476 .0001 * 100	.265 .008 * 99	.355 .0003 * 100	.322 .001 * 99	.027 .791 100	-.173 .085 100	-.086 .394 100
Q 2.5 North			1.0 58	.907 .0001 * 58	.254 .054 58	.323 .014 * 57	.368 .004 * 58	.235 .076 58	.115 .390 58	-.083 .534 58	-.080 .550 58
Q 2.5 South				1.0 62	.245 .055 62	.233 .070 61	.337 .007 * 62	.254 .046 * 62	.154 .232 62	-.095 .464 62	-.022 .866 62
Q 2.6 (a) Sleep					1.0 100	.504 .0001 * 99	.412 .0001 * 100	.398 .0001 * 99	.005 .957 100	-.150 .136 100	-.092 .363 100
Q 2.6 (b) Appetite						1.0 99	.493 .0001 * 99	.346 .0005 * 98	.0007 .994 99	-.043 .675 99	.025 .810 99
Q 2.6 (c) Tiredness							1.0 100	.585 .0001 99	.169 .094 100	-.185 .066 100	-.137 .174 100
Q 2.6 (d) Alertness								1.0 99	.169 .094 100	-.224 .026 * 99	-.058 .570 99
L/V Score									1.0 100	-.341 .0005 * 100	-.629 .0001 * 100
F/R Score										1.0 100	-.018 .861 100
E/M Score											1.0 100

4.2

Examining the correlations between the rating scales in Table 17:

i) The perceived fatigue travelling north or south is highly intercorrelated ($P < 0.001$).

ii) The perceived fatigue travelling west is highly correlated with that for journeys north or south ($P < 0.001$).

iii) There appears to be a significant correlation between symptoms of travel fatigue (sleep disturbance, appetite disturbance, tiredness and reduced alertness) and journeys in an easterly or westerly direction (P all < 0.01) but no discernible difference between travel in a specific direction, east or west.

iv) There is no significant correlation between the response for easterly travel and that for travel in any other direction.

Scale Consistency

Responses to each of the Questions 2.5 and 2.6 in the Traveller Profile Questionnaire aim to measure some aspect of the individuals perception of the severity of travel fatigue. Question 2.5 relates to the direction of travel and Question 2.6 to specific symptoms.

So far in the analysis of the results, each response has been treated separately. However, it should be recognised that they are all measuring fatigue. To examine whether the questions provided an internally consistent measure, an analysis was carried out to calculate Cronbach α, a reliability coefficient, the value of which ranges from 0 to 1 with high values of α indicating a consistent or coherent scale (Cronbach 1951).

4.2

Table 18 restricts the analysis to those subjects without missing data for responses to Questions 2.5 and 2.6. The table demonstrates the effect on the value of α obtained if a particular response is deleted and indicates the correlation of that response with the total score.

Table 18 - Correlation coefficients and Cronbach α scores for responses to Questions 2.5 and 2.6

Overall value of Cronbach α = 0.816

Deleted Response	Correlation With Total	Cronbach α
Q 2.5 E	0.334	0.819
Q 2.5 W	0.520	0.797
Q2.5 N	0.603	0.787
Q 2.5 S	0.555	0.793
Q 2.6 a)	0.576	0.789
Q 2.6 b)	0.558	0.792
Q 2.6 c)	0.604	0.785
Q 2.6 d)	0.540	0.794

The overall value for Cronbach α of 0.816 confirms the internal consistency of the scale of fatigue. In addition, it can be seen that deletion of the response to each question in turn does little to affect the overall consistency (with the possible exception of the response to Question 2.5E which is highly correlated with symptom responses but not with other directions of travel).

On reviewing the data it is clear that the lowest number of responses were obtained for perception of travel fatigue following a journey in a northerly and southerly direction (58 and 62 responses respectively). As a result, in order to increase the sample size under consideration, an identical analysis was carried out omitting Questions 2.5N and 2.5S.

The results are detailed in Table 19.

4.2

Table 19 - Correlation coefficients and Cronbach α scores for selected responses to Questions 2.5 and 2.6

Overall value of Cronbach α = 0.774

Deleted Response	Correlation With Total	Cronbach α
Q 2.5 E	0.341	0.779
Q 2.5 W	0.409	0.768
Q 2.6 a)	0.620	0.713
Q 2.6 b)	0.574	0.727
Q 2.6 c)	0.612	0.719
Q 2.6 d)	0.572	0.728

The overall value of Cronbach α once again indicates coherence, although not as pronounced as when the analysis involved a larger number of questions, but was restricted to a smaller number of subjects. The anomalous measures appear to be the responses to Questions 2.5E and 2.5W from which it may be inferred that they are not measuring the same entity as Questions 2.6a), 2.6b), 2.6c) and 2.6d) and the likelihood of this is considered in more detail later. However, in order to take acount of both direction and perceived symptomatology the subsequent analysis employed the responses to all questions. The correlation coefficients for each response with the total score (see Table 19) were used as weighting factors to calculate an overall measure of "Fatigue" using stepwise multiple regression. This was then used to examine its dependence on a number of independent variables including age, Flexibility/Rigidity score, Languidness/Vigorousness score, Eveningness/Morningness score, alcohol consumption, experience of long haul flights and naps .

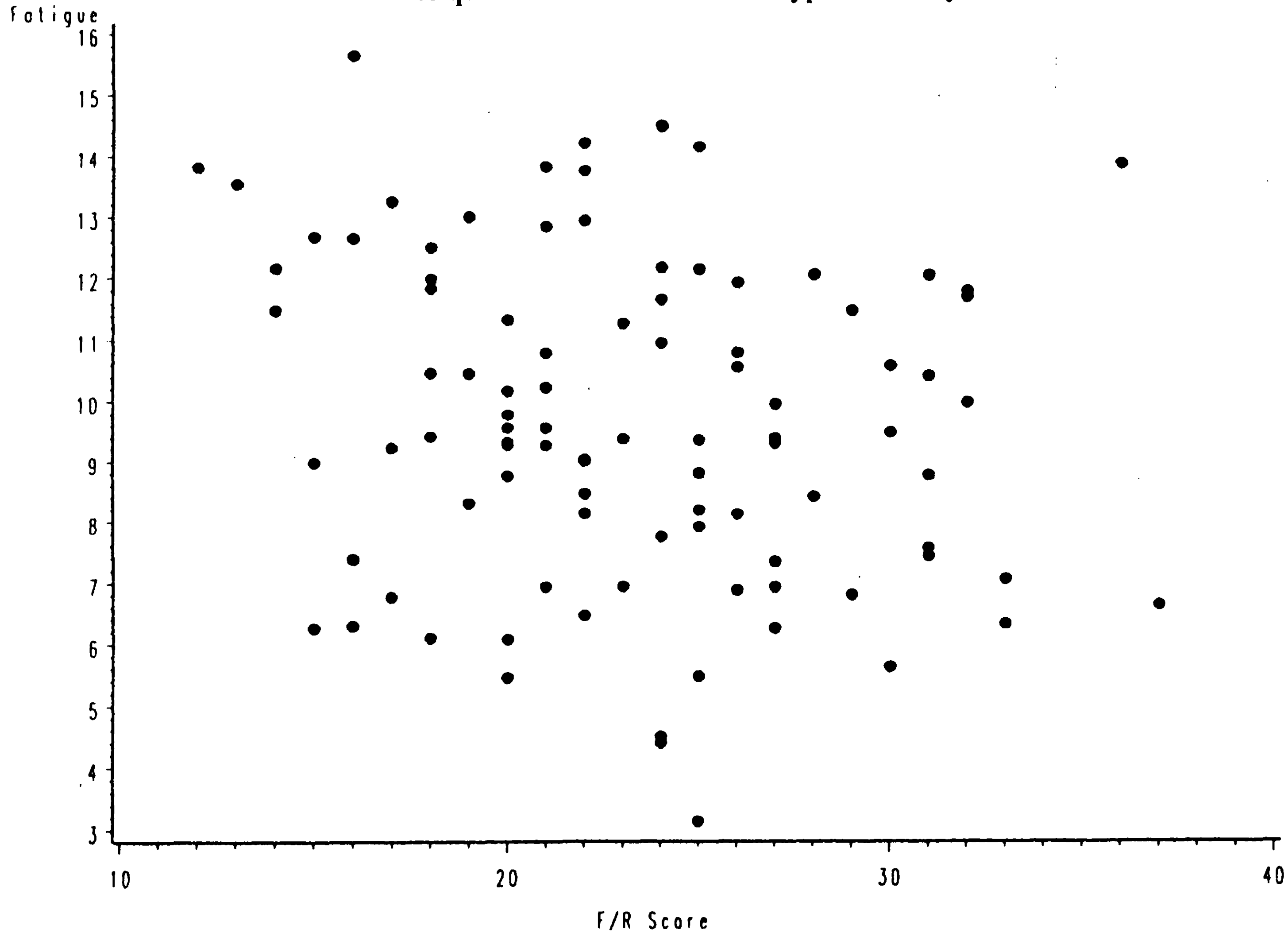
The only variable that entered the regression was that of the Flexibility/ Rigidity (F/R) score, which interestingly in Table 17 has been shown to be correlated with Question 2.6d). This provided an equation of the form:

"Fatigue" = 12.07 - 0.1 F/R Score

The square of the multiple correlation coefficient (R^2) was however only 0.045 indicating that this measure of "Fatigue" accounted for less than 5% of the variance and confirmed that the Circadian Type Inventory and Eveningness/Morningness scales could not be used alone in any predictive capacity to identify those individuals who are likely to suffer most from the effects of travel fatigue, see scatter diagram, Figure 3.

The conclusion therefore is that although the measurement scales are in themselves reliable, none of the variables derived act individually in a predictive capacity.

Figure 3 **Plot of derived variable 'Fatigue' versus Flexibility/Rigidity score obtained from responses to questions in the Circadian Type Inventory**



4.3 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - STUDY SUBJECTS

As indicated in Section 3.7 Phase 2 - Performance Measurement Study - Enrolment, a total of 27 subjects were recruited into this phase of the study of whom 23 also contributed to Phase 1 with the remaining 4 subjects failing to provide usable data for either phase of the study.

During the author's employment with AEA Technology (United Kingdom Atomic Energy Authority), 25 individuals were approached and of these 24 were recruited. The one individual who declined to be involved in the study did so because he felt that the project had no personal relevance to him. The remaining 3 subjects were recruited from British Airways.

The first 24 subjects were in employment with the following organisations:

21 with AEA Technology

1 with an American company whose Occupational Health Service was provided by AEA Technology

2 with Oxford University

Following recruitment, each subject was allocated a unique Subject Identification Number in the range 1 - 27. During the course of Phase 2 of the study, a total of 7 subjects, all of whom were employed by AEA Technology, were withdrawn. As previously mentioned, 4 individuals failed to provide usable data for either phase of the study, (Subject Identification Numbers 6, 13, 15 and 16), and the remaining 3, (Subject Identification Numbers 1, 3 and 4), although providing data for Phase 1, were excluded from Phase 2, see Table 20.

4.3

Table 20 - Reasons for withdrawal of subjects in Phase 2

Subject No.	Trips Completed	Reason for Withdrawal
1	1	Withdrawn by author. Subject moved to USA and would no longer be making regular transatlantic trips.
3	1	Withdrawn by author at time of move to BA. Subject's job had changed and was unlikely to complete 5 trips in time allowed.
4	2	Withdrawn by author at time of move to BA. Subject's job had changed and was unlikely to complete 5 trips in time allowed.
6	0	Withdrawn by author. Subject's job had changed and involved only short haul travel.
13	0	Subject withdrew for personal reasons. Could not undertake the commitment to comply with project protocol.
15	0	Subject withdrew for personal reasons. Could not undertake the commitment to comply with project protocol.
16	2	Withdrawn by author at time of move to BA. Poor compliance.

Subjects 3, 4 and 16 were withdrawn by the author at the time of his change of employment to British Airways in April 1994. They had completed only 4 trips between them and it was felt unlikely that they would meet their full quota of 5 trips in the time allowed. Three further volunteers were subsequently recruited from within British Airways.

At the end of data collection, the 20 subjects remaining had completed a total of 88 trips, although, unfortunately, only 86 trips provided usable data due to faults with the Psion Organisers whilst subjects were overseas. Within these 86 trips, 11 subjects had successfully completed all 5 trips and a further 6 had completed 4 trips each (see Appendix VIII). The original protocol (Appendix I) had required that each subject make 5 round-trips, giving an overall total of 100. The final number was therefore somewhat short of the anticipated total and there were three principal reasons for this shortfall:

4.3

i) The job content of some subjects changed during the course of the study such that they were making fewer long haul trips.

ii) Two Psion Organisers developed faults whilst the subjects were overseas and therefore no data were available for these trips.

iii) Two Psion Organisers were lost in the post and were therefore unavailable to the subjects for their trips.

4.4 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - DATA PREPARATION

As outlined in Section 3.15, at the end of each trip, the subject was instructed to return the Psion Organiser, together with its datapak, to the author. The datapak was then sent to Peter Totterdell at the MRC/ESRC Social and Applied Psychology Unit in Sheffield for downloading on to a 3½" computer disc.

As indicated in Section 4.3, the twenty subjects involved in this study completed a total of 86 round-trips during the course of data collection. For each subject and each trip there were up to six files:

MOOD	subjective rating scales	see Section 3.11
SRT	serial choice reaction time	see Section 3.11
PROBE	memory search task	see Section 3.11
SLEEP	sleep diary	see Section 3.12
DAILY	diary of affect and alcohol consumption	see Section 3.13

and, if applicable,

NAP	nap diary	see Section 3.14

It was therefore necessary to amalgamate the data from each of the trips and to present it in a form which was suitable for analysis. Each file was identified by its name followed by the Subject Identification Number (*user id* in Sections 3.11 to 3.14). The first task was therefore to rename each file incorporating both the Subject Identification Number and Trip Number into the new name such that the file MOOD 052 represented the MOOD file for Subject 5, Trip 2. This task of renaming was repeated for all files.

Under each file name, data was identified by a date and time stamp followed by figures corresponding to the measures indicated in Sections 3.11 to 3.14, e.g.

MOOD052 TUE 13 APR 10:10:01,2,7,10,8

Because each data record was of variable length, it was necessary to read the data into SAS, the statistical analysis package available to the author, using spaces as delimiters between valid data items. For this reason, each data file was globally edited replacing the ',' with a 'space'. In the example above, the resulting data was therefore transformed to:

MOOD052 TUE 13 APR 10:10:01 2 7 10 8

Dedicated programs were required for each of the six data files to ensure that the correct time shift was applied to the time stamp for data collected whilst overseas and in addition, to tag the data obtained on each day with a day number. As the principal interest in this study was the number of time zones that the subject had crossed during their trip, it was necessary to take into account changes between Greenwich Mean Time and British Summer Time when calculating the appropriate time shift for data collected overseas.

The day number was arbitrarily designated as Day 0 for the day of travel, and, therefore, provided the subject had complied with the instructions, Day Numbers would run from Day -7 through Day 0 to Day +7 for the outward portion of the trip and Day -1 through Day 0 to Day +7 for the return journey.

Once again, it was necessary to create these programs manually for each subject and each trip, inserting the Subject Identification Number, Trip Number, appropriate time zone shift and dates of travel in order that the data contained in the file could be labelled with the correct Trip and Day Number and the time stamps for data collected overseas converted to local time.

Day Numbers were allocated separately for the outward and return journeys and therefore a subject whose first trip was of 3 days duration to the United States would have the numbering sequence detailed in Table 21.

4.4

Table 21 - Day numbering for a 3 day trip to the United States

	Outward Departure (am)	Return Departure (late pm)
Day Number	-7	
	-6	
	-5	
	-4	
	-3	
	-2	
	-1	
	0	
	1	
	2	-1
	3	0
	4	1
	5	2
	6	3
	7	4
	8	5
	9	6
	10	7

This system was adopted as it enabled the outward and return trips to be considered separately during data analysis should this be required.

4.4

Although each of the SAS programs were specific to the files to which they referred, e.g. MOOD052, SRT264, the MOOD (subjective rating scales) files were completed either as part of the TEST sequence or with the DAILY file in the ENDDAY diary. The origin of each was clearly identified in the Psion data sets (see Section 3.11). When the MOOD file had been completed with the TEST routine, no specific precautions with regard to day numbering needed to be taken. However, when it had been completed as part of the ENDDAY diary, the task of allocating day numbers was complicated by the fact that some subjects chose to complete their ENDDAY diary the morning after the day to which it referred. The SAS program was therefore written to ensure that if the diary had been completed before 12 noon, local time, it was assumed to refer to the previous day and the Day Number altered accordingly in both the DAILY and corresponding MOOD data files.

The remaining information from the outward and returned journey questionnaires (Appendices IVa and IVb) were encoded into ASCII format and stored on a second 3½" computer disc for integration in subsequent data analysis.

4.5 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - DATA ANALYSIS

Following input of the trip data in a form that could be analysed by SAS, it was necessary to examine the completeness of the data sets and to address the problem of missing data.

Between them, the subjects completed 86 round-trips and these are listed by Subject Identification Number in Appendix VIII. However, in summary form, they are also listed by Trip Number in Table 22.

Table 22 - Table of number of trips completed by Trip Number

Trip Number	Number of Trips
1	20
2	20
3	18
4	17
5	11

As indicated in Section 3.9 Phase 2 - Performance Measurement Study - Study Timetable, subjects were required to undertake the TEST sequence on rising, at lunchtime (12^{00} to 14^{00}) and before their evening meal (18^{00} to 20^{00}). However, on reviewing the data, it is clear that the time bands over which the TEST sequence was completed were actually much wider than requested and therefore for the purposes of analysis, it was necessary to divide the data into appropriate Time Periods, see Table 23.

4.5

Table 23 - Time Periods for the completion of the TEST Sequence

Time Period	Time of Day	Local Time
1	On Rising	Before 10^{00}
2	Lunchtime	10^{00} - 15^{59}
3	Before Evening Meal	16^{00} - 20^{00}
4		After 20^{00}

As shown in Table 23, Time Period 4 corresponds to times after 20^{00} when subjects are more likely to have consumed alcohol. It is probable that this will have affected their cognitive performance and therefore their ability to perform the TEST sequences which will be taken into account during the course of data analysis.

In order to assess the data sets, an examination was made of the number of TEST sequences that had been performed in each Time Period for each Trip Number, irrespective of the Day Number. For this purpose, the Memory Search Task (file name PROBE, see Section 3.11) was used as an example, see Table 24.

Table 24 - Table of number of Memory Search Task sequences peformed by Time Period and Trip Number

Time Period	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5
1	265	231	205	179	137
2	179	127	112	95	72
3	119	108	81	78	56
4	155	126	130	130	89

It was possible to examine these figures in more detail by amalgamating all five trips, but breaking down the number of Memory Search Task sequences performed in each Time Period by Day Number. The numbering sequence

4.5

used for this, and all subsequent analyses, has previously been described in Section 4.4 and employs Day 0 as the day of outward travel, see Table 25.

Table 25 - Table of number of Memory Search Task sequences performed by Time Period and Day Number across all trips

Day Number	Time Period			
	1	2	3	4
-3	10	8	4	5
-2	11	8	7	15
-1	35	32	15	34
0	63	54	25	24
1	41	36	32	41
2	73	43	38	38
3	75	40	26	45
4	73	42	31	39
5	75	29	29	37
6	69	42	29	41
7	62	30	27	30
8	53	25	25	27
9	43	26	18	27
10	42	17	15	25
11	39	14	15	20
12	31	15	15	22
13	30	15	8	17
14	25	10	15	18

The subjects each completed a maximum of 5 trips of variable length. However, even taking account of the shortest trips, compliance with the protocol would have provided data for three TEST sequences daily over a minimum day span of Day -1 to 7. Over Time Periods 1, 2 and 3, subjects completed a total of 1166 TEST sequences out of a possible 2322 across the nine days from Day -1 to Day 7 providing an overall compliance rate of 50.2% although this level rose to 64.4% (1495 TEST sequences) when Time Period 4 was included.

4.5

However, in order to provide further information regarding the distribution of data, a more detailed analysis of compliance was undertaken by separately examining each of Trips 1 to 5 (see Table 26). This shows a similar pattern to that seen in Table 24, but, as a result of subjects completing less than the desired five round-trips and because of reduced compliance, Table 26 highlights the limited amount of data available from later trips.

Table 26 - Table of number of Memory Search Task sequences performed by Time Period and Day Number for each of Trips 1-5

Day No.	Time Period 1						Time Period 2						Time Period 3						Time Period 4					
	Trip No.	1	2	3	4	5	Trip No.	1	2	3	4	5	Trip No.	1	2	3	4	5	Trip No.	1	2	3	4	5
-3		7	1	2	0	0		5	1	2	0	0		2	1	0	1	0		4	0	1	0	0
-2		7	2	2	0	0		4	2	2	0	0		4	1	2	0	0		7	4	3	1	0
-1		10	6	9	7	3		13	5	8	4	2		5	7	1	0	2		8	8	8	6	4
0		11	14	16	16	6		19	12	8	6	9		3	6	7	5	4		10	1	5	7	1
1		10	10	9	7	5		14	7	6	6	3		8	7	7	7	3		9	11	9	7	5
2		16	16	16	13	12		10	11	8	11	3		9	7	11	6	5		8	7	8	9	6
3		19	16	16	13	11		7	8	10	6	9		8	6	4	4	4		8	11	10	10	6
4		18	18	16	13	8		15	9	8	5	5		7	6	7	8	3		9	8	7	10	5
5		18	20	15	13	9		12	7	5	4	1		8	6	4	6	5		10	5	11	7	4
6		17	18	13	12	9		12	9	5	5	11		6	8	6	4	5		7	8	11	9	6
7		17	12	15	10	8		9	10	6	4	1		6	10	2	5	4		7	5	7	4	7
8		14	14	9	9	7		6	5	2	7	5		9	6	4	3	3		6	5	7	7	2
9		13	13	10	3	4		6	6	6	4	4		7	4	2	3	2		5	9	3	6	4
10		11	9	8	9	5		6	5	3	1	2		3	4	4	2	2		7	5	3	5	5
11		11	12	5	6	5		3	4	5	1	1		2	5	2	3	3		3	5	4	4	4
12		11	6	3	5	6		4	4	3	2	2		3	5	1	3	3		6	4	3	5	4
13		8	7	6	5	4		4	1	3	4	3		1	1	2	2	2		1	5	3	4	4
14		6	4	4	6	5		2	0	3	3	2		4	6	2	1	2		2	4	3	5	4

4.5

The data set was subsequently used in a preliminary, although more detailed analysis examining the results for the Mean Correct Response Time in the Memory Search Task by Number of Subjects and Day Number in Time Period 1 for Trips 1-5 looking for the appearance of any obvious day or trip effects. These results are shown in Table 27.

Table 27 - Table of Mean Correct Response Time in 100ths second for true positives and true negatives in the Memory Search Task by number of subjects and Day Number in Time Period 1 for Trips 1-5

Day No.	No. of Subjects	Mean Correct Response Time Across 40 Stimuli (100ths sec)			
		Min	Max	Mean	SD
TRIP 1					
-1	10	66.35	134.74	95.51	22.31
0	11	74.99	164.73	108.31	28.01
1	10	72.87	132.36	106.70	18.60
2	16	67.37	204.47	102.32	30.81
3	19	73.38	212.94	114.08	36.89
TRIP 2					
-1	6	57.69	114.85	82.08	20.54
0	14	56.02	119.24	84.10	17.46
1	10	76.89	159.87	102.43	25.40
2	16	58.72	140.38	86.97	20.36
3	16	67.36	149.62	90.58	24.53
TRIP 3					
-1	9	53.65	114.23	76.52	19.55
0	16	56.45	159.36	83.37	25.15
1	9	54.87	118.60	80.92	17.39
2	16	55.81	163.14	86.06	30.40
3	16	56.50	122.43	79.26	17.21
TRIP 4					
-1	7	56.00	98.03	72.91	14.24
0	16	58.37	134.99	88.72	28.08
1	7	65.87	149.71	99.60	29.85
2	13	54.99	113.97	79.17	17.64
3	13	55.77	110.58	78.69	17.36
TRIP 5					
-1	3	56.37	64.72	60.27	4.21
0	6	59.20	134.55	79.27	27.57
1	5	64.75	143.81	99.11	36.67
2	12	60.52	142.69	88.75	27.94
3	11	58.24	113.07	79.60	16.48

4.5

From these brief analyses, it is clear that the data sets, particularly for the high Day and Trip Numbers are incomplete. In addition, from the results shown in Table 27, Trip 1 appears at first inspection to provide results, at least for the Memory Search Task, which are markedly different from subsequent trips, and, across most trips, the Mean Correct Response Time appears to show a general deterioration on Day 1 before subsequent improvement.

However, it is clear that one of the problems with the data in Table 27 is that there is no certainty that the same subjects are being compared from day to day and from trip to trip as the technique employed examines only the number of subjects contributing, not the individual Subject Identification Numbers.

As a result, a further analysis was performed specifically employing the Subject Identification Numbers for individuals providing Memory Search Task (PROBE) data for Time Period 1 using different spans of Day Number to assess the presence or absence of an optimum day span for use in subsequent analyses. These results are shown in Tables 28, 29 and 30.

Table 28 - Table of subjects providing Memory Search Task data on Days -1, 1, 2 and 3 for each trip

Trip No.	Subject Identification Number																			
1			07				11	12	14	17	18	19	20					25		27
2			07					12		17			20		22					
3							11	12		17			20		22			25		
4							11	12				19			22					
5			07				11					19								

Table 29 - Table of subjects providing Memory Search Task data on Days -1, 1, 2, 3, 4, ,5 ,6 and 7 for each trip

Trip No.	Subject Identification Number																			
1			07						14		18	19	20					25		
2													20							
3													20		22			25		
4																				
5																				

Table 30 - Table of subjects providing Memory Search Task data on Days 0, 1, 2 and 3 for each trip

Trip No.	Subject Identification Number																			
1	05		07		09		11		14	17	18	19	20							27
2	05		07		09		11	12		17			20		22		24	25		
3	05				09		11	12		17		19	20		22			25	26	
4	05						11	12		17		19			22			25		
5	05		07				11			17		19							26	

4.5

Table 30 clearly demonstrates that, although all subjects had been requested to complete the TEST sequence on Day Numbers -1, 1, 2, 3, 4, 5, 6 and 7, examination of the data by Subject Identification Number indicates that few of them complied consistently each day and that the optimum day span required to maximise the number of complete data sets for subsequent analysis appears to be Day Numbers 0, 1, 2 and 3.

Finally, in order to look more critically at the data, a further analysis based on the Memory Search Task was undertaken using the three subjects who had provided data on Days 0, 1, 2 and 3 for all 5 trips. Table 31 shows the Mean Correct Response Time in 100ths second obtained for true positive and true negative responses for Time Period 1 in Subjects 5, 11 and 17 on Days 0, 1, 2 and 3 by Trip Number.

Table 31 - Table of Mean Correct Response Time in 100ths second for true positives and true negatives in the Memory Search Task for Time Period 1 in Subjects 5, 11 and 17 on Days 0, 1, 2 and 3 by Trip Number

Trip Number	Day Number			
	0	1	2	3
1	108.09	113.02	111.73	108.54
2	88.56	99.16	80.15	109.86
3	78.27	80.62	80.39	78.75
4	82.57	-	88.41	91.88
5	67.19	82.00	87.14	81.27

On inspection there does appear to be a trip effect with improvement in the Mean Correct Response Time for Trips 2, 3, 4 and 5 when compared to Trip 1. A finding which is repeated in all other data files of cognitive performance. It is known that few subjects completed performance tests for the full seven days prior to departure on their first overseas trip and this has therefore resulted in a marked residual practice effect during Trip 1.

4.5

In addition to the trip effect apparent in Table 31, there also appears to be a day effect, similar to that seen in Table 27, with some prolongation in the Mean Correct Response Time on Day 1 compared to Day 0 which subsequently returns towards the base-line value in Trips 1 and 3.

In summary, each trip for each subject provided a series of measurements of subjective and objective parameters at different times on different days, although all were repeat measures on the same individual. Therefore, to take account of the possible correlation between measures for the same individual, the correct analysis to perform will be a Repeated Measures Analysis of Variance. The practice effect highlighted above may be allowed for by the removal of Trip 1 from the analysis and each subject's dataset subsequently transposed into a matrix where each row is composed of repeat measures within a trip.

The only difficulty with this approach is that the analysis relies heavily upon there being no missing data. If there is a missing data point for any combination within a trip then those data are excluded from the final modelling. Due to the poor complete compliance across all Time Periods and Day Numbers, many of the 66 remaining trips (following removal of Trip 1), do not meet the criteria for inclusion, leaving an inadequate number of datasets to simultaneously measure day and time of day effects (see Tables 28-30). For this reason, various combinations of Day Number are used ranging from Day -1 to Day 7 in combination with single Time Periods, principally Time Period 1, where there is more data to attempt to identify the presence or absence of a day effect and, in each case, the total number of trips from which data has been obtained is specified.

4.5

A further limitation is the requirement to use Day 0 as the base-line value for many of the analyses. As indicated in Section 4.4, Day 0 was the arbitrary Day Number assigned to the day of travel and subjects were specifically asked not to undertake the Psion based tasks during their journey on the basis that:

i) the day was atypical

ii) it was impossible to assign the correct time shift to the data obtained during the journey, and

iii) the test conditions were likely to be less controllable than under normal circumstances.

Despite this, it is clear from Table 30 that in order to analyse the results by Time Period, Day Number and Trip Number, the paucity of TEST sequences make it necessary on occasions to use data obtained on Day 0 and this has therefore been employed in the Repeated Measures Analysis of Variance without any form of time shift being applied as a base-line 'pre-trip' value for the parameters under scrutiny.

4.6 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - RESULTS

A total of 20 subjects contributed to Phase 2 of the study, all of whom were part of the larger population who participated in Phase 1 - Traveller Profile Study. The subjects were required to complete 5 long haul round-trips each during the course of data collection which extended from March 1993 to February 1995. The proposed total of 100 trips was unfortunately not fulfilled and, by the end of data collection, a total of 88 trips had been completed of which 86 provided usable data. The subjects consisted of 2 females with an age range of 29 to 31 years (mean 30 years, standard deviation 1 year) and 18 males with an age range 30 to 64 years (mean 41.6 years, standard deviation 9.6 years). Overall, the population age range was 29 to 64 years with a mean of 40.4 years and standard deviation of 9.8 years (ages correct at time of recruitment to the study).

During the course of the study, data was collected on affect, well-being and cognitive performance using a Psion Organiser. As indicated in Section 4.5 Phase 2 - Performance Measurement Study - Data Analysis, individual compliance caused some problems and hindered data interpretation. Table 22 details the total number of trips completed by Trip Number and this is expanded in Table 32 to differentiate between the number of outbound Eastward and Westward journeys undertaken by the subjects.

4.6

Table 32 - Table of number of trips by direction outbound and Trip Number

Trip Number	Outbound Eastward	Outbound Westward	Total No. of Trips
1	9	11	20 (23%)
2	12	8	20 (23%)
3	9	9	18 (21%)
4	11	6	17 (20%)
5	8	3	11 (13%)
Total	49 (57%)	37 (43%)	**86 (100%)**

As indicated in Section 4.5, results obtained for Trip 1 were excluded from some of the analyses due to the persistence of a practice effect. Although there is an adequate split between outbound journeys in an Easterly and Westerly direction, it has already been demonstrated in Table 26 that relatively few subjects provided data consistently, either during the course of their time overseas or following their return home. Whilst many subjects did undertake short business trips to the United States and Far East, the average trip length for all journeys was 9.8 days (standard deviation 6.2 days, range 2 to 25 days). Reduced compliance resulted in few subjects continuing to use the Psion for the whole of the required period, and, in view of the limited data beyond Day 7, it was not possible to separate outward and return journeys during the analyses. As a result, day numbering based on the departure day for outward trips only has been employed.

4.7 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - RESULTS - MOOD, AFFECT AND WELL-BEING

As indicated in Section 3.9 Phase 2 - Performance Measurement Study - Study Timetable, the central requirement in this part of study was for subjects to use the Psion Organiser during their waking hours to assess affect, well-being and cognitive performance before, during and after their long haul overseas trips.

As part of the TEST sequence and also in the ENDDAY diary, subjects were required to complete MOOD ratings indicating their subjective level of Alertness, Cheerfulness, and Calmness using a 20 point bipolar rating scale (see Section 3.11). An analysis has been made of each of these in turn in an attempt to identify the presence of a Day or Time of Day effect for the rating under scrutiny.

Alertness as part of TEST sequence Tables (33 - 36)

Examining the subjective rating of Alertness performed as part of the TEST sequence, the following results were obtained:

4.7

Table 33 - Table of subjective rating of Alertness performed as part of the TEST sequence in Time Period 1 on Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Mean	Standard Error
0	9.87	0.52
1	8.73	0.33
2	9.73	0.63
3	9.07	0.69

$F(3,12) = 1.28$; $Pr>F = 0.3268$

Table 33 shows no apparant Day effect for Alertness over the day span under consideration. However, an examination of Days 4, 5, 6 and 7 increases the number of trips under consideration, see Table 34.

4.7

Table 34 - Table of subjective rating of Alertness performed as part of the TEST sequence in Time Period 1 on Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 28 Trips	
Day Number	Mean	Standard Error
4	9.39	0.44
5	9.68	0.50
6	9.75	0.44
7	9.82	0.47

F(3,25) = 0.73 ; Pr>F = 0.5415

Table 34 also fails to indicate the presence of a Day effect for Alertness, but, on examining the overall pattern across Days 0 to 7 for Time Period 1 based on 6 Trips, there is some evidence of a Day effect, see Table 35.

4.7

Table 35 - Table of subjective rating of Alertness performed as part of the TEST sequence in Time Period 1 on Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Mean	Standard Error
0	10.00	0.52
1	9.17	0.54
2	9.00	0.82
3	7.83	0.83
4	9.33	0.33
5	8.50	0.56
6	10.17	0.40
7	9.83	0.54

Univariate analysis of variance - $F(7,35) = 2.28$; $Pr>F = 0.0509$

The univariate analysis of variance demonstrates a Day effect approaching statistical significance at the 5% level. However, further examination indicates that one day alone (Day 5) is demonstrating statistical significance when being compared with the base-line (Day 0) ($F(1,5) = 7.11$; $Pr > F = 0.0446$). Unfortunately, the analysis is based on only 6 trips and there are no data available beyond Day 7 making it difficult to demonstrate any clear trend and come to any conclusion regarding the significance of the finding.

4.7

<u>**Cheerfulness as part of TEST sequence Tables (36 - 38)**</u>

Similar analyses were also performed for the other subjective rating scales, Cheerfulness and Calmness.

Table 36 - Table of subjective rating of Cheerfulness performed as part of the TEST sequence in Time Period 1 on Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Mean	Standard Error
0	10.33	0.62
1	10.93	0.69
2	10.93	0.64
3	10.47	0.55

F(3,12) = 0.56 ; Pr>F = 0.6522

As with Alertness, by altering the period of observation and examining Days 4, 5, 6 and 7, it is possible to increase the number of trips under scrutiny, see Table 37.

4.7

Table 37 - Table of subjective rating of Cheerfulness performed as part of the TEST sequence in Time Period 1 on Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 28 Trips	
Day Number	Mean	Standard Error
4	10.57	0.63
5	10.89	0.52
6	11.00	0.53
7	10.29	0.56

$F(3,25) = 0.87$; $Pr>F = 0.4698$

The statistical analysis fails to demonstrate the presence of a Day effect over either day span. However, further examination in Time Period 1 on Days 0, 1, 2, 3, 4, 5, 6 and 7 over 6 Trips does once again provide a result bordering on statistical significance, see Table 38.

4.7

Table 38 - Table of subjective rating of Cheerfulness performed as part of the TEST sequence in Time Period 1 on Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Mean	Standard Error
0	10.67	0.67
1	11.83	0.83
2	12.00	0.89
3	10.67	0.42
4	12.67	1.36
5	11.17	0.83
6	12.67	0.88
7	11.67	0.76

Univariate analysis of variance - F(7,35) = 2.20 ; Pr>F = 0.0585

Further examination again indicates that a single day (Day 6) demonstrates statistical significance when being compared with the base-line (Day 0) (F (1,5) = 8.57 ; Pr > F = 0.0327).

Calmness as part of TEST sequence (Tables 39 - 41)

Finally, an examination was made of the subjective rating scale for Calmness.

4.7

Table 39 - Table of subjective rating of Calmness performed as part of the TEST sequence in Time Period 1 on Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Mean	Standard Error
0	10.20	0.79
1	11.07	0.62
2	11.47	0.68
3	10.40	0.74

$F(3,12) = 0.65$; $Pr>F = 0.5985$

Table 40 - Table of subjective rating of Calmness performed as part of the TEST sequence in Time Period 1 on Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 28 Trips	
Day Number	Mean	Standard Error
4	10.71	0.56
5	11.25	0.50
6	10.68	0.47
7	10.86	0.49

$F(3,25) = 0.85$; $Pr>F = 0.4776$

4.7

Table 41 - Table of subjective rating of Calmness performed as part of the TEST sequence in Time Period 1 on Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Mean	Standard Error
0	13.00	0.63
1	13.00	1.15
2	12.83	1.28
3	12.33	0.84
4	12.83	1.42
5	12.00	1.03
6	11.67	0.76
7	11.67	1.09

Univariate analysis of variance - $F(7,35) = 0.64$; $Pr>F = 0.7204$

The results presented in Tables 39 to 41 show no overall Day effect.

Further subjective measures of well-being, together with additional ratings for Alertness, Cheerfulness and Calmness based on the whole day were completed by the subjects as part of the ENDDAY diary (see Section 3.13) and demonstrated a better level of compliance than encountered previously allowing Day -1 to be used as the base-line in some of the analyses. As previously outlined, the rating scales for Alertness, Cheerfulness and Calmness were recorded using a 20 point bipolar rating scale together with additional ratings using a 20 point unipolar scale in response to the following questions:

4.7

Think about today and rate your overall:

Alertness?

Cheerfulness?

Calmness?

Effectiveness?

How much did you experience the following:

Mental Demand?

Time Pressure?

Disorientation?

Appetite Disturbance?

Physical Tiredness?

The results of the individual analyses examining the presence or absence of a Day effect in the scales under consideration are shown in Tables 42 - 50.

4.7

Alertness as part of ENDDAY diary Tables (42 - 44)

Table 42 - Table of subjective rating of Alertness performed as part of the ENDDAY diary on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	12.79	0.77
0	10.93	0.59
1	11.21	0.70
2	10.79	0.92
3	10.86	0.78

$F(4,10) = 4.05$; $Pr>F = 0.0332$

Table 42 indicates the presence of a Day effect, significant at the 5% level which is further confirmed when comparing each day in turn with the base-line (Day -1) (Day 0, $F(1,13) = 14.36$; $Pr > F = 0.0023$; Day 1, $F(1,13) = 10.35$; $Pr > F = 0.0067$; Day 2, $F(1,13) = 6.17$; $Pr > F = 0.0274$).

It is clear that the Alertness rating gradually returns towards the pre-trip value and this is emphasised when comparing Day 3 with the base-line (Day -1) where the difference no longer reaches statistical significance ($F(1,13) = 3.27$; $Pr > F = 0.0937$)

Reducing the day span under consideration increases the number of trips available for study although necessitates the use of Day 0 as the base-line measurement, see Table 43.

4.7

Table 43 - Table of subjective rating of Alertness performed as part of the ENDDAY diary on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	11.00	0.51
1	10.04	0.62
2	9.48	0.78
3	10.04	0.56

F(3,20) = 0.90 ; Pr>F = 0.4567

Table 43 provides no indication of an overall Day effect. However, as a direct result of the improved compliance in completing the ENDDAY diary, the increased number of trips available for analysis made it possible to examine the data omitting the day of travel, thereby observing the original aim of the study, and employing Day -1 as the base-line, see Table 44.

Table 44 - Table of subjective rating of Alertness performed as part of the ENDDAY diary on Days -1, 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	12.27	0.55
1	10.04	0.63
2	10.12	0.61
3	10.88	0.57

F(3,23) = 7.42 ; Pr>F = 0.0012

4.7

Table 44 shows a clear Day effect and, in particular, Days 1 and 2 demonstrate markedly lower ratings of Alertness compared with the pre-trip values, significant at the 1% level (F (1,25) = 20.39 ; Pr > F = 0.0001 and F (1,25) = 15.76 ; Pr > F = 0.0005 respectively)

Cheerfulness as part of the ENDDAY diary (Tables 45 - 47)

A similar sequence of analyses were carried out for the subjective rating scale of Cheerfulness.

Table 45 - Table of subjective rating of Cheerfulness performed as part of the ENDDAY diary on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	11.14	0.80
0	11.71	0.74
1	11.64	0.73
2	11.79	0.71
3	11.14	0.67

F(4,10) = 0.31 ; Pr>F = 0.8616

4.7

Table 46 - Table of subjective rating of Cheerfulness performed as part of the ENDDAY diary on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	11.26	0.67
1	10.78	0.60
2	10.96	0.68
3	10.17	0.58

F(3,20) = 0.89 ; Pr>F = 0.4654

Tables 45 and 46 provide no indication of a Day effect.

Table 47 - Table of subjective rating of Cheerfulness performed as part of the ENDDAY diary on Days -1, 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	10.73	0.55
1	11.42	0.52
2	11.81	0.44
3	11.58	0.45

F(3,23) = 1.65 ; Pr>F = 0.2045

Likewise, Table 47 does not appear to demonstrate an overall Day effect. However, when comparing each day in turn with the base-line (Day -1), the subjective rating of Cheerfulness is found to be better on Day 2 (F (1,25) = 5.39 ; Pr > F = 0.0287) and significant at the 5% level.

4.7

Calmness as part of the ENDDAY diary (Tables 48 - 50)

Repeating the analyses for the rating of Calmness.

Table 48 - Table of subjective rating of Calmness performed as part of the ENDDAY diary on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	10.79	0.81
0	11.50	0.77
1	12.07	0.73
2	11.64	0.82
3	10.50	0.40

$F(4,10) = 3.31$; $Pr>F = 0.0569$

Table 48 indicates the presence of a Day effect which is approaching significance at the 5% level. This is further borne out when comparing each day with the base-line (Day -1) (Day 1, $F(1,13) = 5.48$; $Pr > F = 0.0358$; Day 2, $F(1,13) = 4.22$; $Pr > F = 0.0607$) indicating a significantly increased rating on Day 1 although inspection of the data shows that the level returns to that seen before departure by Day 3.

4.7

Table 49 - Table of subjective rating of Calmness performed as part of the ENDDAY diary on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	10.30	0.80
1	11.26	0.66
2	10.78	0.69
3	9.65	0.46

$F(3,20) = 3.79$; $Pr>F = 0.0265$

Table 49 again demonstrates a Day effect significant at the 5% level, although no univariate tests approached significance when comparing each day in turn with the base-line (Day 0).

Table 50 - Table of subjective rating of Calmness performed as part of the ENDDAY diary on Days -1, 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	9.96	0.62
1	11.23	0.54
2	11.19	0.55
3	10.65	0.39

$F(3,23) = 3.37$; $Pr>F = 0.0358$

Finally, Table 50 also demonstrates a Day effect which is confirmed when looking at each day compared with the base-line (Day -1). Day 1 demonstrates a difference, significant at the 5% level ($F(1,25)$ =

6.12 ; Pr > F = 0.0205) and Day 2, at the 1% level (F (1,25) = 10.19 ; Pr > F = 0.0038), again showing significantly increased Calmness in the early part of the trip overseas.

Effectiveness (Tables 51 - 53)

Table 51 - Table of subjective rating of Effectiveness performed on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	12.86	1.14
0	12.43	1.13
1	11.29	1.18
2	9.57	1.32
3	11.93	1.11

F(4,10) = 1.54 ; Pr>F = 0.2630

Table 51 indicates that the perceived Effectiveness on Day 2 appears to be less than the pre-trip value (Day -1) although only just bordering on statistical significance (F (1,13) = 4.21 ; Pr > F = 0.0609). Reducing the day span under consideration increases the number of trips available for study although necessitates the use of Day 0 as the base-line measurement, see Table 52.

4.7

Table 52 - Table of subjective rating of Effectiveness performed on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	12.17	0.87
1	10.17	0.93
2	9.30	1.08
3	11.17	0.82

$F(3,20) = 1.80$; $Pr>F = 0.1794$

Table 52 provides no indication of an overall Day effect although the ratings for Days 1 and 2 are both statistically lower than Day 0 and significant at the 5% level ($F(1,22) = 4.31$; $Pr > F = 0.0499$ and $F(1,22) = 4.74$; $Pr > F = 0.0404$ respectively).

4.7

Table 53 - Table of subjective rating of Effectiveness performed on Days -1, 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	12.96	0.72
1	10.96	0.71
2	10.12	0.80
3	12.39	0.73

$F(3,23) = 4.05$; $Pr>F = 0.0189$

Table 53 on the other hand does show an overall Day effect, and, in particular, Days 1 and 2 demonstrate significantly lower ratings of Effectiveness compared with the pre-trip value significant at the 5% ($F(1,25) = 5.00$; $Pr > F = 0.0345$) and 1% ($F(1,25) = 9.09$; $Pr > F = 0.0058$) levels respectively.

4.7

<u>Mental Demand (Tables 54 - 56)</u>

A similar sequence of analyses were carried out for the subjective rating scale of Mental Demand.

Table 54 - Table of subjective rating of Mental Demand performed on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	11.64	1.35
0	9.21	1.14
1	8.79	1.25
2	9.00	1.13
3	9.71	1.41

F(4,10) = 0.51 ; Pr>F = 0.7300

Table 55 - Table of subjective rating of Mental Demand performed on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	9.09	0.94
1	9.35	1.02
2	8.39	0.89
3	11.65	1.24

F(3,20) = 1.97 ; Pr>F = 0.1507

4.7

Although there is clearly no overall Day effect for Days -1 to 3 in Table 54 or Days 0 to 3 in Table 55, the subjective rating for Mental Demand on Day 3 is different from Day 0 (Table 55) and significant at the 5% level ($F(1,22) = 4.69$; $Pr > F = 0.0414$).

As before, using Day -1 as the base-line and omitting Day 0, a more marked Day effect becomes apparent which, as with Effectiveness, shows a significant difference between Days 1 and 2 and the pre-trip value ($F(1,25) = 11.45$; $Pr > F = 0.0024$ and $F(1,25) = 6.28$; $Pr > F = 0.0190$ respectively), see Table 56.

Table 56 - Table of subjective rating of Mental Demand performed on Days -1 , 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	12.77	0.87
1	8.62	0.80
2	9.58	0.86
3	11.12	0.96

$F(3,23) = 3.88$; $Pr>F = 0.0222$

These findings indicate a reduction in Mental Demand in the early phase of the trip and it is interesting to observe that the results appear to show a decrease from Day -1 to Day 1. This may be explained by the fact that subjects either rested or had reduced workloads in the first day or two after their arrival overseas and in an attempt to clarify this, an examination was made of the work/rest patterns of the subjects contributing to Table 56, see Table 57.

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Table 57 - Table of work days and rest days by Day Number and number of trips for the 26 Trips contributing to Table 56

Day Type across 26 Trips	Day Number			
	-1	1	2	3
Work Day	19	12	17	19
Rest Day	7	14	9	7

Statistical analysis using the χ^2 method does not provide evidence of significance ($\chi^2 = 5.50$; $Pr > \chi^2 = 0.139$) although the results are nonetheless suggestive that the proportion resting on Day 1 is greater than the other days examined and this may account for the observed reduction in Mental Demand in the early phase of the trip .

The subjective rating scales of Time Pressure and Disorientation were not analysed formally. The scale of Time Pressure was poorly completed by subjects and therefore no detailed examination was undertaken. The scale of Disorientation was included to encompass the non-specific symptoms of travel fatigue frequently experienced after long haul flights. Unfortunately, despite explanation, the understanding of this term by the subjects was poor and, therefore, once again, detailed analysis was not attempted.

4.7

Appetite Disturbance (Tables 58 - 60)

As previously, three separate analyses were performed.

Table 58 - Table of subjective rating of Appetite Disturbance performed on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	1.29	0.29
0	3.57	1.10
1	5.07	1.10
2	5.86	1.54
3	6.36	1.33

$F(4,10) = 3.55$; $Pr>F = 0.0473$

The results for Days -1, 0, 1, 2 and 3 (Table 58) show a marked Day effect which is further emphasised when comparing each day with the base-line (Day -1), all of which demonstrate statistical significance at better than the 5% level (Day 0, $F(1,13) = 5.20$; $Pr > F = 0.0401$; Day 1, $F(1,13) = 11.42$; $Pr > F = 0.0049$; Day 2, $F(1,13) = 8.43$; $Pr > F = 0.0123$; Day 3, $F(1,13) = 13.42$; $Pr > F = 0.0029$).

Table 59 illustrates the results obtained when examining Days 0, 1, 2 and 3. In this analysis, there is no Day effect apparent which almost certainly reflects the fact that Day 0 is not a true base-line and confirms the likelihood that subjects will already be aware of some subjective effect of Appetite Disturbance on the day of travel.

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Table 59 - Table of subjective rating of Appetite Disturbance performed on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	3.91	0.93
1	6.57	1.17
2	6.04	1.08
3	6.22	1.09

$F(3,20) = 2.33$; $Pr>F = 0.1052$

Finally, an examination of Days -1, 1, 2 and 3 once again yields the most conclusive results, see Table 60.

Table 60 - Table of subjective rating of Appetite Disturbance performed on Days -1, 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	1.15	0.15
1	3.96	0.72
2	4.35	0.94
3	4.27	0.88

$F(3,23) = 5.69$; $Pr>F = 0.0046$

As previously, a comparison of each day in turn with the base-line (Day -1) demonstrates differences all highly significant at the 1% level (Day 1, $F(1,25) = 15.25$; $Pr > F = 0.0006$; Day 2, $F(1,25) = 11.46$; $Pr > F = 0.0024$

Day 3, F (1,25) = 12.45 ; Pr > F = 0.0016) confirming a marked Day effect with increasing Appetite Disturbance following long haul travel.

Physical Tiredness (Tables 61 - 63)

Similar analyses were performed for the rating of Physical Tiredness.

Table 61 - Table of subjective rating of Physical Tiredness performed on Days -1, 0, 1, 2 and 3 across Trip Numbers 2-5 based on 14 Trips

Day Number	Mean	Standard Error
-1	5.86	1.32
0	8.14	1.12
1	8.29	1.27
2	9.36	1.52
3	9.79	1.33

F(4,10) = 2.85 ; Pr>F = 0.0819

Table 62 - Table of subjective rating of Physical Tiredness performed on Days 0, 1, 2 and 3 across Trip Numbers 2-5 based on 23 Trips

Day Number	Mean	Standard Error
0	9.26	0.93
1	10.78	1.17
2	10.87	1.18
3	11.48	1.07

F(3,20) = 1.95 ; Pr>F = 0.1544

4.7

Table 63 - Table of subjective rating of Physical Tiredness performed on Days -1, 1, 2 and 3 across Trip Numbers 2-5 based on 26 Trips

Day Number	Mean	Standard Error
-1	7.96	1.01
1	11.00	1.12
2	11.08	1.14
3	10.81	0.94

$F(3,23) = 3.68$; $Pr>F = 0.0267$

In the case of Physical Tiredness, Table 63 alone demonstrates a Day effect. As with previous rating scales, there is a difference, significant at the 1% level when comparing each day separately with the base-line (Day -1) (Day 1, $F(1,25) = 8.79$; $Pr > F = 0.0066$; Day 2, $F(1,25) = 9.27$; $Pr > F = 0.0054$; Day 3, $F(1,25) = 9.03$; $Pr > F = 0.0060$) indicating increased Physical Tiredness during the trip compared to pre-trip levels.

In addition to subjective rating scales of affect and well-being, the ENDDAY diary also required subjects to document their daily alcohol consumption in units. To assist them in this, each subject was given guidelines as to the quantity of various alcoholic beverages in one unit. Overall the results do appear to show an increase in alcohol consumption whilst overseas compared with home, see Tables 64 to 66.

4.7

Table 64 - Table of number of subjects consuming alcohol by number of units and Day Number across all Trips 1-5.

		Number of Units of Alcohol Consumed											
Day Number	Total No of Trips	0	1	2	3	4	5	6	7	8	9	10	21
-1	34	16	6	5	3	1	3	0	0	0	0	0	0
0	32	8	2	4	4	6	2	4	1	1	0	0	0
1	50	11	3	8	7	6	7	6	0	0	1	0	1
2	53	8	3	14	8	8	7	2	2	1	0	0	0
3	58	11	9	7	12	8	4	4	2	1	0	0	0
4	55	8	9	8	13	6	7	1	0	1	1	1	0
5	46	7	8	9	8	5	5	2	0	0	1	1	0
6	48	12	9	6	7	8	4	1	1	0	0	0	0
7	44	11	6	8	4	6	4	4	0	0	0	1	0

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Table 65 - Table of alcohol consumption by Day Number across all Trips 1-5

Day Number	Mean Alcohol Consumption	Standard Deviation
-1	1.29	1.62
0	2.97	2.58
1	3.30	3.39
2	2.94	2.00
3	2.71	2.11
4	2.84	2.23
5	2.74	2.26
6	2.23	1.91
7	2.55	2.31

Table 66 - Table of alcohol consumption on Days -1, 1, 2 and 3 across Trips 2-5 based on 26 Trips

Day Number	Mean Alcohol Consumption	Standard Deviation
-1	1.27	0.31
1	3.54	0.80
2	3.62	0.39
3	3.19	0.43

$F(3,23) = 6.71$; $Pr>F = 0.0020$

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Data from all 5 trips was employed in compiling Tables 64 and 65 and therefore in order to maintain consistency with the earlier analyses of the subjective rating scales, Table 66 limits the assessment to Trips 2 to 5 and encompasses the same 26 trips employed in Tables 44, 47, 50, 53, 56, 60 and 63. There is a clear Day effect and, in addition, a highly significant difference in alcohol consumption when comparing each day separately with the base-line (Day -1) (Day 1, $F_{(1,25)} = 6.90$; $Pr > F = 0.0145$; Day 2, $F_{(1,25)} = 21.83$; $Pr > F = 0.0001$; Day 3, $F_{(1,25)} = 12.93$; $Pr > F = 0.0014$) indicating increased alcohol consumption whilst overseas.

The final variable to be considered was that of sleep. Information regarding the subjects' sleep pattern was recorded on rising each morning in the STARTDAY diary and comprised data on Length of Sleep, number of Episodes of Waking and Quality of Sleep (see Section 3.12). Each has been examined in turn and the results presented in Tables 67 to 70.

All assessments of Length of Sleep were calculated in seconds for the convenience of SAS, the statistical package available to the author, although Table 67 also provides the data in hours for ease of comparison.

As outlined in Section 4.4, Day 0 was the arbitrary Day Number assigned to the day of travel. The journeys all involved long haul flights and will therefore have resulted in some disruption to the subject's sleep pattern. This will have been particularly true for eastbound flights, all of which will have passed through a local night resulting in the subject not arriving at the destination until Day 1. As discussed earlier, despite being requested not to provide data on Day 0, some subjects nonetheless completed Psion tests and diaries and their results have been recorded in the tables.

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Table 67 - Table of Length of Sleep on Days -1, 0, 1, 2 and 3 across Trips 2-5 based on 15 Trips

Day Number	Mean Length of Sleep (Seconds)	Standard Deviation	Mean Length of Sleep (Hours)
-1	26700	848.0	7.42
0	25036	1177.6	6.95
1	26560	2276.8	7.38
2	26204	1168.4	7.28
3	24648	2049.6	6.85

$F(4,11) = 0.55$; $Pr>F = 0.7049$

Table 67 shows no Day effect for the Length of Sleep. However, unlike the subjective rating scales of affect and well-being, compliance for the completion of the STARTDAY diary meant that there were no additional data available to enable a separate analysis to be undertaken on Days -1, 1, 2 and 3. As a result, the same 15 Trips were included in further calculations by simply omitting the results from Day 0. General inspection of Table 67 indicates that this will further reduce any possible Day effect and the resultant test statistic ($F(3,12) = 0.32$; $Pr > F = 0.8098$) bears this out.

As outlined, all subjects participating in Phase 2 of the study had also taken part in Phase 1 - Traveller Profile Study. The questionnaire in Phase 1 included items on sleep, and, in particular, asked subjects to indicate their preferred time of going to bed and rising, together with their ideal length of sleep. These results have been compared with the actual findings from the STARTDAY diary and are presented in Table 68

4.7

Table 68 - Table of comparisons of ideal and actual Length of Sleep across Trips 1-5 for all subjects

A = Average Length of Sleep in seconds across all Days and all Trips
B = Average Length of Sleep in seconds on Days 1, 2 and 3 across all Trips
C = Average Length of Sleep in seconds based on responses to Question 4.1, Traveller Profile Questionnaire
D = Average Length of Sleep in seconds based on preferred times of going to bed and getting up as indicated in Question 4.3, Traveller Profile Questionnaire

Comparison	No. of Subjects	Mean Difference (seconds)	Standard Error (seconds)	Mean Difference (minutes)
① = C - D	20	-2670	753.6	-44.5
② = A - D	20	-3166	1029.9	-52.8
③ = B - D	20	-2789	1364.3	-46.5
④ = A - C	20	-496	927.9	-8.3
⑤ = B - C	20	-119	1255.0	-2.0

Examining the results presented in Table 68:

Comparison ① looks at the difference between the Length of Sleep that subjects feel they require and their ideal Length of Sleep based on their preferred times of going to bed and geting up. The result indicates that subjects feel they need less sleep than they would take given no constraints. This difference is significant at the 1% level.

Comparison ② examines the difference between the subjects' average Length of Sleep taken across all Days and all Trips with their ideal Length of Sleep based on their preferred times of going to bed and getting up. This indicates that their actual sleep is less than the amount of sleep they would take given no constraints and the difference significant at the 5% level.

Comparison ③ looks at the difference between the subjects' average Length of Sleep on Days 1, 2 and 3 across all Trips with their ideal Length of Sleep based on their preferred times of going to bed and getting up. Again, their actual sleep is less than the amount of sleep they would take given no constraints and the difference also significant at the 5% level.

Comparison ④ again examines the subjects' average Length of Sleep taken across all Days and all Trips but on this occasion compares it with the Length of Sleep that they feel they require. As previously, their actual Length of Sleep is shorter than their ideal although the difference is not statistically significant.

Finally, Comparison ⑤ compares the average Length of Sleep on Days 1, 2 and 3 across all Trips with the Length of Sleep that subjects feel they require. The difference demonstrated amounts to less than 2 minutes and is not statistically significant.

It is clear that there is a marked difference between subjects' assessment of their requirement for sleep (Question 4.1, Traveller Profile Questionnaire) and their Length of Sleep based on preferred times of going to bed and getting up. The latter is likely to overestimate the actual requirement for sleep as, given no constraints, the majority of persons would retire earlier and rise later than they actually need. As a result, the response to Question 4.1 ("How much sleep do you feel you need each day?") is likely to give the more accurate prediction of the actual requirement for Length of Sleep, and, based on this, there appears to be no significant difference between actual and predicted Length of Sleep across all days of observation irrespective of whether or not pre-trip days (Comparison ④) are included.

Returning once again to the Psion data. In addition to the Length of Sleep, the number of Episodes of Waking were also recorded, although the data were compromised by poor compliance. The only day span providing sufficient data for analysis was Days -1, 0, 1, 2 and 3 and the results presented in Table 69. Episodes of Waking were assessed to be rare events and were therefore transformed using the equation:

$$(\text{Episodes of Waking})' = [\sqrt{\text{Episodes of Waking}}] + [\sqrt{(\text{Episodes of Waking} + 1)}]$$

to stabilise the variance in subsequent analyses.

Table 69 - Table of transformed data for number of Episodes of Waking on Days -1, 0, 1, 2 and 3 across Trips 2-5 based on 16 Trips

Day Number	Transformed Data for No. of Episodes of Waking	Standard Deviation
-1	1.81	0.32
0	2.12	0.38
1	2.45	0.22
2	2.49	0.35
3	3.24	0.54

F(4,12) = 1.10 ; Pr>F = 0.4005

Although there is no statistically significant Day effect, there is a general tendency for there to be more Episodes of Waking following long haul flights compared with the base-line on Day -1. Omission of the data for Day 0 still fails to show an overall Day effect ($F(3,13) = 1.36$; $Pr > F = 0.2976$) but when considering Day 3 alone and comparing this with Day -1, the difference does approach statistical significance ($F(1,15) = 4.02$; $Pr > F = 0.0635$).

The final variable to be considered was Quality of Sleep. As with previous subjective rating scales, subjects were required to rate the quality of their sleep using a familiar 20 point bipolar rating scale and the results are shown in Table 70.

Table 70 - Table of subjective rating of Quality of Sleep for Days -1, 0, 1, 2 and 3 across Trips 2-5 based on 16 Trips

Day Number	Mean Quality of Sleep	Standard Deviation
-1	11.38	0.97
0	10.44	1.22
1	8.50	1.05
2	10.38	0.93
3	8.63	1.08

$F(4,12) = 1.40$; $Pr>F = 0.2923$

As with the other sleep parameters, no additional data were available to allow a separate analysis for Days -1, 1, 2 and 3. However, omission of Day 0 from the results above also fails to demonstrate a Day effect ($F(3,13) = 2.02$; $Pr > F = 0.1616$) although it is clear from inspecting the data, confirmed on statistical analysis, that there is a significant difference between

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Day 1 and the base-line (Day -1) ($F(1,15) = 4.75$; $Pr > F = 0.0457$) indicating a diminution in the Quality of Sleep on the first night overseas.

4.8 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - RESULTS - COGNITIVE PERFORMANCE

In addition to subjective ratings of affect and well-being, the TEST sequences also contained tests of cognitive performance, the Serial Choice Reaction Time test and Memory Search Task. As with the subjective ratings and taking account of the possible correlation between measures from the same individual, a Repeated Measures Analysis of Variance was performed using varying spans of Day Number and differing Time Periods to identify possible Day or Time of Day effects for the parameter under scrutiny.

Serial Choice Reaction Time Test

The Serial Choice Reaction Time test required the subject to complete two blocks, each of 80 stimuli, with their reaction times being averaged over both blocks to provide the test results.

As outlined in Section 4.5, the number of trips used for each analysis comprises the total number of trips provided by all subjects supplying complete data sets for the Time Period and Day Number under consideration from the 66 trips available (20 Trip 2's, 18 Trip 3's, 17 Trip 4's and 11 Trip 5's).

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Table 71 - Table of Mean Choice Reaction Time in 100ths second for correct responses with both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Mean Choice Reaction Time	Standard Error
0	47.86	1.35
1	49.04	1.72
2	47.90	1.56
3	48.57	1.73

F(3,12) = 0.51 ; Pr>F = 0.6846

Repeating the analysis in Table 71 for Time Period 2.

Table 72 - Table of Mean Choice Reaction Time in 100ths second for correct responses with both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 2 ; 6 Trips	
Day Number	Mean Choice Reaction Time	Standard Error
0	48.37	3.95
1	47.60	3.84
2	49.03	3.82
3	46.84	3.65

F(3,3) = 1.71 ; Pr>F = 0.3358

4.8

There appears to be no demonstrable Day effect across either Time Periods 1 or 2 although it is clear that the compliance level for the provision of the data required for Table 72 allowed less than 10% of the available trips to be included. To compound matters, the 6 trips used were not unfortunately part of the larger data set used to compile Table 71 and, as a result, it was not possible to compare the Time Periods and investigate the presence or absence of a Time of Day effect for the days under scrutiny.

In the case of Time Period 1, limited data were also available to allow an examination of the presence or absence of a Day effect over the extended period Day 0 to Day 7, see Table 73.

Table 73 - Table of Mean Choice Reaction Time in 100ths second for correct responses with both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Mean Choice Reaction Time	Standard Error
0	45.77	1.33
1	47.28	2.50
2	46.48	1.54
3	46.60	1.64
4	47.19	0.99
5	48.22	1.55
6	44.13	1.32
7	44.88	1.16

Univariate analysis of variance - $F(7,35) = 1.49$; $Pr>F = 0.2022$

4.8

Once again there is no apparent Day effect. However, by concentrating on Days 4-7, it is possible to increase the data set to 29 trips. The results of this further analysis are shown in Table 74, although, once again, no Day effect is evident.

Table 74 - Table of Mean Choice Reaction Time in 100ths second for correct responses with both left and right hands in the Serial Choice Reaction Time test performed on each of Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 29 Trips	
Day Number	Mean Choice Reaction Time	Standard Error
4	45.42	0.77
5	45.46	0.90
6	44.20	0.96
7	44.57	-

F(3,26) = 1.55 ; Pr>F = 0.2246

In addition to looking at the Mean Choice Reaction Time, it was also possible to examine the Percentage Accuracy for both hands and Tables 75 to 78 repeat the analyses for the same day spans and Time Periods as previously employed.

4.8

Table 75 - Table of Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Percentage Accuracy	Standard Error
0	98.36	0.31
1	98.36	0.35
2	97.65	0.45
3	98.44	0.30

F(3,12) = 0.97 ; Pr>F = 0.4403

Table 76 - Table of Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 2 ; 6 Trips	
Day Number	Percentage Accuracy	Standard Error
0	90.65	5.55
1	93.94	2.96
2	91.19	4.97
3	92.25	4.91

F(3,3) = 3.80 ; Pr>F = 0.1511

4.8

Table 77 - Table of Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Percentage Accuracy	Standard Error
0	98.33	0 53
1	98.22.	0.63
2	98.02	0.38
3	98.43	0.53
4	96.86	0.90
5	98.32	1.05
6	97.39	0.88
7	97.29	0.73

Univariate analysis of variance - F(7,35) = 1.29 ; Pr>F = 0.2844

Table 78 - Table of Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 29 Trips	
Day Number	Percentage Accuracy	Standard Error
4	94.86	1.21
5	95.25	1.20
6	94.91	1.18
7	94.48	1.12

F(3,26) = 0.91 ; Pr>F = 0.4478

4.8

These analyses again show no evidence of a Day effect. However, by the nature of the measure under consideration, the data do not constitute a normal distribution and are all condensed within a very narrow range. A transformation was therefore performed to increase the variance of the data. The transformation used in this case was:

$$(\%\ \text{Accuracy})' = \arcsin[\sqrt{(\%\ \text{Accuracy}/100)}] \times (180/\pi)$$

The same analyses were repeated and the results are presented in Tables 79 to 82.

Table 79 - Table of Transformed Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Transformed Percentage Accuracy	Standard Error
0	83.45	0.90
1	83.68	1.01
2	81.89	0.94
3	83.26	0.66

F(3,12) = 1.50 ; Pr>F = 0.2645

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Table 80 - Table of Transformed Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 2 ; 6 Trips	
Day Number	Transformed Percentage Accuracy	Standard Error
0	75.96	5.33
1	77.95	3.56
2	75.78	4.76
3	78.37	5.21

$F(3,3) = 16.18$; $Pr>F = 0.0234$

4.8

Table 81 - Table of Transformed Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Transformed Percentage Accuracy	Standard Error
0	83.03	1.17
1	83.32	1.69
2	82.13	0.85
3	83.28	1.16
4	80.34	1.50
5	85.11	2.54
6	81.92	2.08
7	80.99	1.34

Univariate analysis of variance - $F(7,35) = 1.52$; $Pr>F = 0.1942$

4.8

Table 82 - Table of Transformed Percentage Accuracy for both left and right hands in the Serial Choice Reaction Time test performed on each of Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 29 Trips	
Day Number	Transformed Percentage Accuracy	Standard Error
4	79.00	1.41
5	80.25	1.57
6	79.42	1.50
7	78.24	1.35

$F(3,26) = 1.86$; $Pr>F = 0.1615$

Multivariate analysis of variance fails to show any apparent Day effect apart from the rather contradictory result in Table 80 based on only 6 trips. On further analysis, this does demonstrate a difference that approaches statistical significance between the Transformed Percentage Accuracy in Time Period 2 on Day 0 and Day 3 indicating an improvement in accuracy over that time ($F(1,5) = 5.41$; $Pr > F = 0.0675$).

When subjects undertook the Serial Choice Reaction Time test a record was also made of those trials in which the subject failed to respond to the stimulus within 1 second (see Section 3.11). These trials were termed "Gaps" and the number of "Gaps" recorded. These, being rare events, were once again transformed to stabilise the variance before further statistical analysis using the following equation:

4.8

$$(\text{No. of Gaps})' = [\sqrt{\text{No. of Gaps}}] + [\sqrt{(\text{No. of Gaps} + 1)}]$$

Similar analyses were performed yielding the following results, see Tables 83 to 86:

Table 83 - Table of Transformed Number of Gaps in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Transformed Number of Gaps	Standard Error
0	2.097	0.41
1	2.728	0.48
2	2.158	0.37
3	1.928	0.64

$F(3,12) = 1.18$; $Pr>F = 0.3589$

Table 84 - Table of Transformed Number of Gaps in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 2 ; 6 Trips	
Day Number	Transformed Number of Gaps	Standard Error
0	2.739	1.09
1	2.719	0.92
2	2.699	1.17
3	2.452	0.96

$F(3,3) = 0.07$; $Pr>F = 0.9721$

4.8

Table 85 - Table of Transformed Number of Gaps in the Serial Choice Reaction Time test performed on each of Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Transformed Number of Gaps	Standard Error
0	2.065	0.36
1	2.609	0.65
2	1.707	0.32
3	1.471	0.30
4	1.775	0.54
5	1.951	0.44
6	1.707	0.32
7	1.236	0.24

Univariate analysis of variance - $F(7,35) = 1.43$; $Pr>F = 0.2261$

Table 86 - Table of Transformed Number of Gaps in the Serial Choice Reaction Time test performed on each of Days 4, 5, 6, and 7 across Trip Numbers 2-5

	Time Period 1 ; 29 Trips	
Day Number	Transformed Number of Gaps	Standard Error
4	1.352	0.16
5	1.491	0.16
6	1.387	0.14
7	1.220	0.11

$F(3,26) = 0.64$; $Pr>F = 0.5946$

4.8

There is no apparent Day effect in the tables presented. However, further analysis of the data in Table 85 demonstrates a statistically significant difference between the Transformed Number of Gaps on Day 7 and those on Day 0 ($F(1,5) = 8.55$; $Pr > F = 0.0328$). Although based on only 6 trips, the results do show significance at the 5% level and indicate a reduction in the Number of Gaps from Day 0 to Day 7.

Memory Search Task

In addition to the Serial Choice Reaction Time test, the cognitive performance of subjects was further assessed using a modified Sternberg Memory Search Task (1969) employing a set of 7 letters. The Mean Correct Response Time for true positives and true negatives was calculated over a series of 40 trials together with the Proportion of Correct Responses over the same series. As with the Percentage Accuracy in the Serial Choice Reaction Time test, the Proportion of Correct Responses extended only over a very narrow range and therefore to expand the data and increase the variance, the following transformation was performed:

$$(\text{Proportion Correct})' = \arcsin[\sqrt{(\text{Proportion Correct}/100)}] \times (180/\pi)$$

The results obtained for the Memory Search Task are shown in Tables 87 to 90.

4.8

Table 87 - Table of Mean Correct Response Time in 100ths second for true positives and true negatives in the Memory Search Task performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Mean Correct Response Time	Standard Error
0	88.86	5.39
1	89.02	5.36
2	88.72	5.09
3	90.67	5.00

F(3,12) = 0.05 ; Pr>F = 0.9828

Table 88 - Table of Mean Correct Response Time in 100ths second for true positives and true negatives in the Memory Search Task performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 2 ; 6 Trips	
Day Number	Mean Correct Response Time	Standard Error
0	95.90	13.31
1	84.90	8.54
2	82.78	10.18
3	89.02	13.53

F(3,3) = 1.17 ; Pr>F = 0.4497

4.8

Table 89 - Table of Mean Correct Response Time in 100ths second for true positives and true negatives in the Memory Search Task performed on each of Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Mean Correct Response Time	Standard Error
0	84.83	7.14
1	83.29	7.46
2	82.21	4.96
3	83.71	5.91
4	85.08	7.62
5	89.21	5.75
6	83.83	3.92
7	86.83	5.40

$F(7,35) = 0.19$; $Pr>F = 0.9855$

4.8

Table 90 - Table of Mean Correct Response Time in 100ths second for true positives and true negatives in the Memory Search Task performed on each of Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 29 Trips	
Day Number	Mean Correct Response Time	Standard Error
4	83.92	3.73
5	79.97	3.24
6	77.83	2.71
7	80.34	3.29

$F(3,26) = 1.66$; $Pr>F = 0.1994$

There is no apparent Day effect for the Mean Correct Response Time.

As indicated, it was also possible to look at the Transformed Proportion of Correct Responses, see Tables 91 to 94.

4.8

Table 91 - Table of Transformed data for the Proportion of Correct Responses in the Memory Search Task performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 1 ; 15 Trips	
Day Number	Transformed Proportion Correct	Standard Error
0	81.70	2.11
1	81.21	2.04
2	82.35	1.34
3	77.17	2.59

$F(3,12) = 1.61$; $Pr>F = 0.2392$

Table 92 - Table Transformed data for the Proportion of Correct Responses in the Memory Search Task performed on each of Days 0, 1, 2 and 3 across Trip Numbers 2-5

	Time Period 2 ; 6 Trips	
Day Number	Transformed Proportion Correct	Standard Error
0	76.19	4.77
1	71.67	2.79
2	80.73	3.31
3	79.05	4.38

$F(3,3) = 2.76$; $Pr>F = 0.2135$

4.8

Table 93 - Table of Transformed data for the Proportion of Correct Responses in the Memory Search Task performed on each of Days 0, 1, 2, 3, 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 6 Trips	
Day Number	Transformed Proportion Correct	Standard Error
0	83.26	3.25
1	83.87	3.93
2	82.17	2.69
3	77.62	3.49
4	78.08	2.86
5	77.36	1.24
6	77.16	3.06
7	82.14	2.70

Univariate analysis of variance - $F(7,35) = 1.22$; $Pr>F = 0.3161$

4.8

Table 94 - Table of Transformed data for the Proportion of Correct Responses in the Memory Search Task performed on each of Days 4, 5, 6 and 7 across Trip Numbers 2-5

	Time Period 1 ; 29 Trips	
Day Number	Transformed Proportion Correct	Standard Error
4	79.17	1.34
5	80.52	1.25
6	79.72	1.40
7	79.42	1.41

$F(3,26) = 0.23$; $Pr>F = 0.8744$

The results presented in Tables 91 to 94 do not indicate a Day effect using transformed data for the Proportion of Correct Responses in the Memory Search Task.

Interpretation and analysis of the tests of cognitive performance by this method has been severely limited by the poor compliance of subjects necessitating the utilisation of some data sets comprising fewer than 10% of the available trips for particular Time Periods and Day Numbers. Indeed, even by restricting the analysis to Days 0, 1, 2 and 3 for Time Period 1 (before 10^{00} hours), only 15 out of a possible 66 trips were available for examination.

There is no statistically significant Day effect for the Mean Choice Reaction Time, Percentage Accuracy and Number of Gaps in the Serial Choice

Reaction Time test apart from an improvement, significant at better than the 5% level, between the Number of Gaps obtained in Time Period 1 on Day 7 compared with Day 0.

A similar picture is obtained with the Memory Search Task and an analysis based on the Mean Correct Response Time and Proportion of Correct Responses fails to provide any statistically significant evidence of a Day effect.

The method of Repeated Measures Analysis of Variance relies heavily on there being no missing data, and, therefore, in view of the level of complete compliance, it is possible that a Day or Time of Day effect for the results of the tests of cognitive performance has failed to manifest itself in the foregoing analysis. In order to counteract this deficiency and utilise as much of the available data as possible, it is necessary to remove differences between subjects due to the learning effect and combine the data in such a way that it could be thought of as coming from a single subject.

To remove the practice effect, a 7th degree polynomial has therefore been fitted to the data for each individual and the residual from the fitted curve calculated. Following a Z-transformation, these data have then been used in a 2 and 3-way Analysis of Variance.

All five parameters of cognitive performance have been used as before, employing the same transformations where applicable:

Serial Choice Reaction Time Test	-	Mean Choice Reaction Time
	-	Transformed Percentage Accuracy

4.8

- Transformed Number of Gaps

Memory Search Task
- Mean Correct Repsonse Time
- Transformed Proportion of Correct Responses

For each subject, their data for all trips was sequentially listed and an observation number assigned to each data point. A polynomial regression was then fitted to the data set up to order 7, such that:

$$y = ax_1 + bx_2 + cx_3 + dx_4 + ex_5 + fx_6 + gx_7$$

where x_1 = (observation number)

x_2 = (observation number)^2

x_3 = (observation number)^3

x_4 = (observation number)^4

x_5 = (observation number)^5

x_6 = (observation number)^6

x_7 = (observation number)^7

For each regression, the residual value for every data point was then calculated as:

Residual Value = Actual Value - Predicted Value

which provided values for the deviation from the fitted curve. The curve is measuring the trend, or learning effect, and the residual around the curve is therefore a measure of the Day and Time of Day effect. By their very nature, the mean of the residuals is zero. However, a standard deviation may be calculated in the normal way and the Z score estimated using the equation:

$$\text{Z score} = \frac{\text{Residual value - Mean of Residuals}}{\text{Standard Deviation of Residuals}}$$

The purpose of calculating the Z score is to enable the data to be amalgamated as though they are replicates from the same subject. Once the data sets have been constructed in this way, the effects of interest are Day effect, Time of Day effect, and to a lesser extent Trip effect, since by removing the residual practice effect, any Trip effect has largely been lost.

Following data construction, analyses have been performed using a 2-way Analysis of Variance with Day and Time as the main effects and their interaction represented as Day∗Time. The basic format includes all data from Day -1 to Day 7 across Time Periods 1-4.

Interestingly, despite earlier concern regarding the possible effect of alcohol consumption on the results obtained during Time Period 4, restricting the analysis to Time Periods 1, 2 and 3 does not affect any time comparisons, and, as seen, has little effect on the daily means.

4.8

Serial Choice Reaction Time Test

Applying the same sequence to the analyses as previously employed in the Repeated Measures Analysis of Variance and commencing with the Mean Choice Reaction Time, see Table 95.

Table 95 - Table of Day Effect, Time Effect and Day*Time interaction for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Principal Effect/ Interaction	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Pr > F
Day	8	5.42	0.68	0.70	0.6923
Time of Day	3	64.96	21.65	22.34	0.0001
Day*Time	24	39.49	1.65	1.70	0.0190

Table 95 demonstrates the presence of a Time of Day effect and a Day*Time interaction. Further, more detailed exploration of the Day and Time of Day effects can be obtained by ranking the mean scores and carrying out pair-wise comparisons allowing for the number of multiple comparisons under consideration. To this end, a Ryan-Einot-Gabriel-Welsch (REGW) multiple range test has been used with the significance level set at 5%, see Tables 96, 97 and 99.

4.8

Table 96 - Table of ranked Mean Transformed Day Scores for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Day Scores	No. of Observations contributing to Mean	Day Number
0.12	117	-1
0.08	149	7
0.05	185	4
0.03	166	0
-0.01	181	6
-0.03	150	1
-0.06	186	3
-0.06	192	2
-0.08	170	5

In Table 96, the Mean Transformed Day Scores vary from positive to negative. For measurements of reaction time, a positive value indicates worsening or slower responses, whereas a negative value indicates improvement or quickening responses. There are no significant day differences although it is interesting to note that the base-line value (Day -1) represents the poorest performance.

A similar process was also performed for the Transformed Time Scores, see Table 97.

4.8

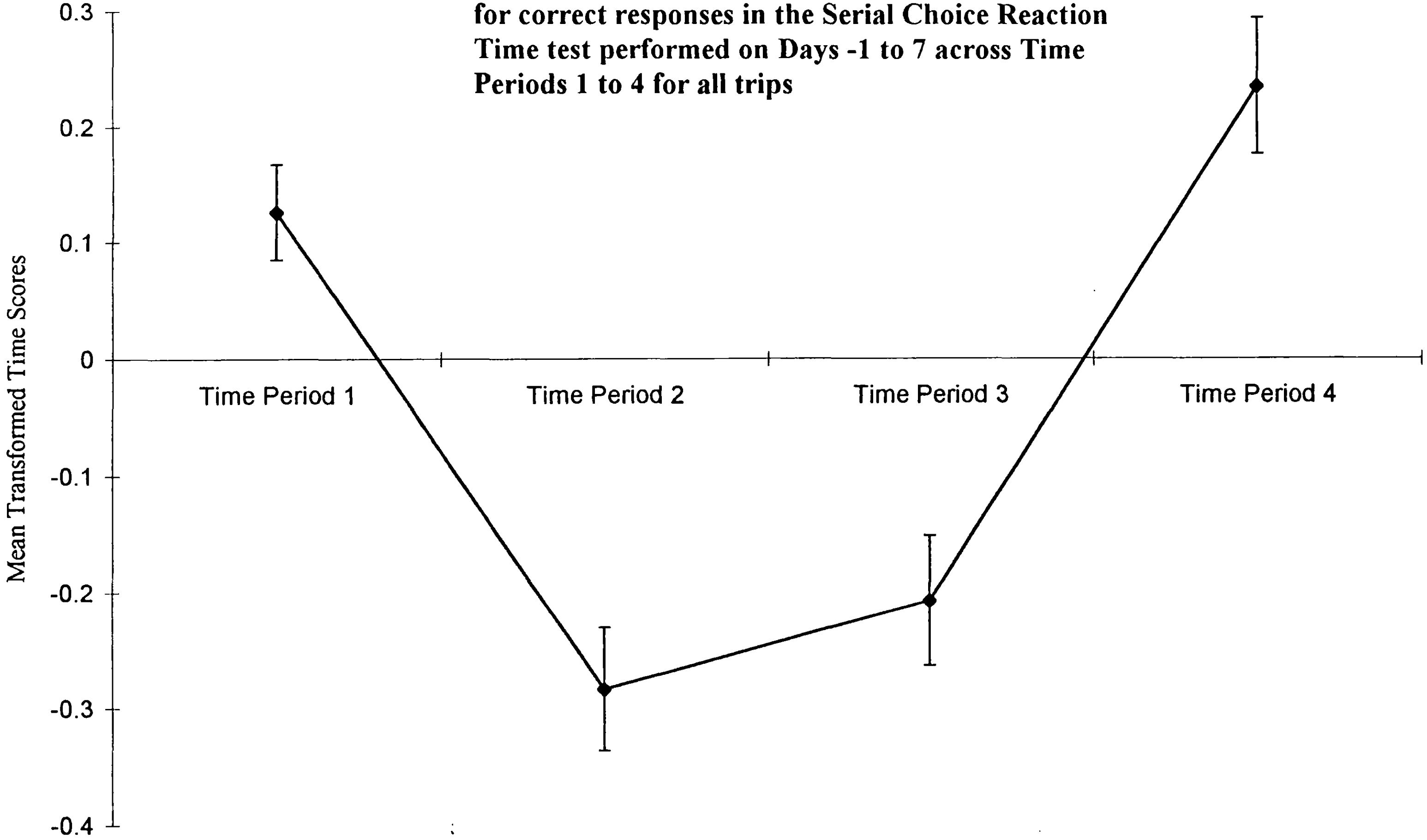
Table 97 - Table of ranked Mean Transformed Time Scores for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Time Scores	No. of Observations contributing to Mean	Time Period
0.23	326	4
0.13	565	1
-0.21	255	3
-0.28	350	2

Values obtained in Time Period 2 (10^{00} - 15^{59}) are clearly the fastest followed by Time Period 3 (16^{00} - 20^{00}), see Figure 4 overleaf. Individual comparisons using the REGW test confirm differences, significant at the 5% level, between Time Period 4 and Time Periods 2 and 3, and Time Period 1 and Time Periods 2 and 3.

Results demonstrating the Day∗Time interaction are represented in Tables 98 and 99 and Figures 5, 6, 7, 8, 9, 10 and 11. Figures 9 and 10, although complex, clearly indicate an interaction but also illustrate well the fact that across all the days under investigation (excluding Day 0), the results obtained in Time Periods 2 and 3 are faster than those at either end of the day and that the pattern is generally sustained across the day span. As may be expected, figures obtained for Time Period 4 are slowest on Days -1 and 1, almost certainly reflecting the cumulative fatigue experienced as a result of the subject's preparation for the trip and the subsequent long haul flight.

Figure 4 **Plot of the overall Mean Transformed Time Scores by Time Period for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips**



4.8

Table 98 - Table of Mean Transformed Time Scores for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 in each of Time Periods 1, 2, 3 and 4 across all trips

Day Number	Time Period	No. of Observations contributing to Mean	Mean Transformed Time Scores	Standard Error
-1	1	36	0.09	0.20
-1	2	32	-0.37	0.20
-1	3	15	-0.30	0.33
-1	4	34	0.80	0.12
0	1	63	0.22	0.12
0	2	54	-0.15	0.12
0	3	25	0.03	0.20
0	4	24	-0.09	0.20
1	1	40	-0.11	0.16
1	2	37	-0.26	0.12
1	3	32	-0.38	0.15
1	4	41	0.53	0.19
2	1	72	-0.01	0.11
2	2	44	-0.21	0.17
2	3	38	-0.07	0.16
2	4	38	0.01	0.12
3	1	74	-0.02	0.11
3	2	42	-0.20	0.15
3	3	25	-0.20	0.20
3	4	45	0.10	0.12
4	1	73	0.40	0.12
4	2	42	-0.22	0.16
4	3	31	-0.32	0.12
4	4	39	-0.03	0.20
5	1	75	0.14	0.11
5	2	29	-0.60	0.13
5	3	31	-0.33	0.14
5	4	35	0.08	0.18
6	1	70	0.16	0.12
6	2	41	-0.38	0.20
6	3	30	-0.28	0.17
6	4	40	0.25	0.24
7	1	62	0.16	0.12
7	2	29	-0.34	0.18
7	3	28	-0.05	0.17
7	4	30	0.42	0.14

Figure 5 **Plot of Mean Transformed Time Scores by Day Number for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 in Time Period 1 across all trips**

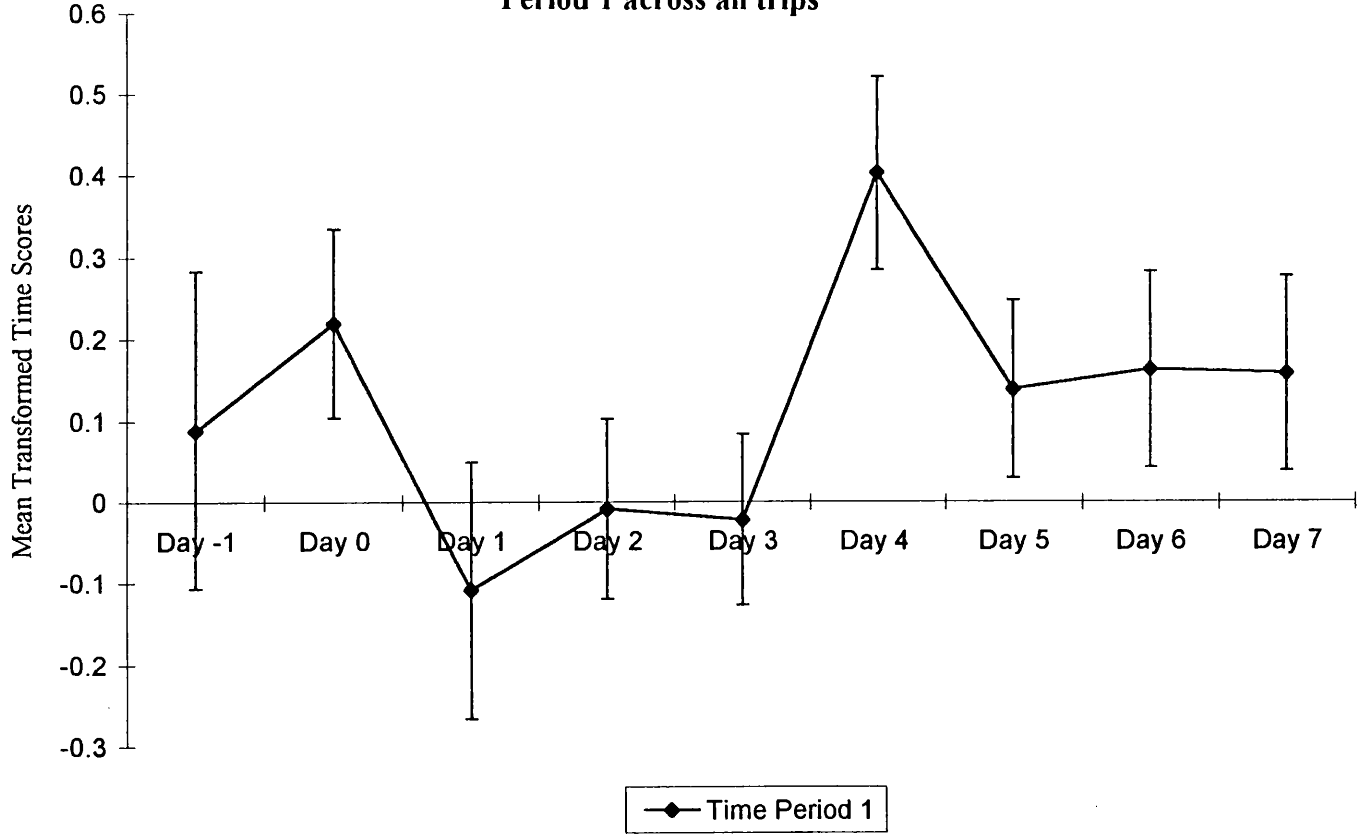


Figure 6 **Plot of Mean Transformed Time Scores by Day Number for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 in Time Period 2 across all trips**

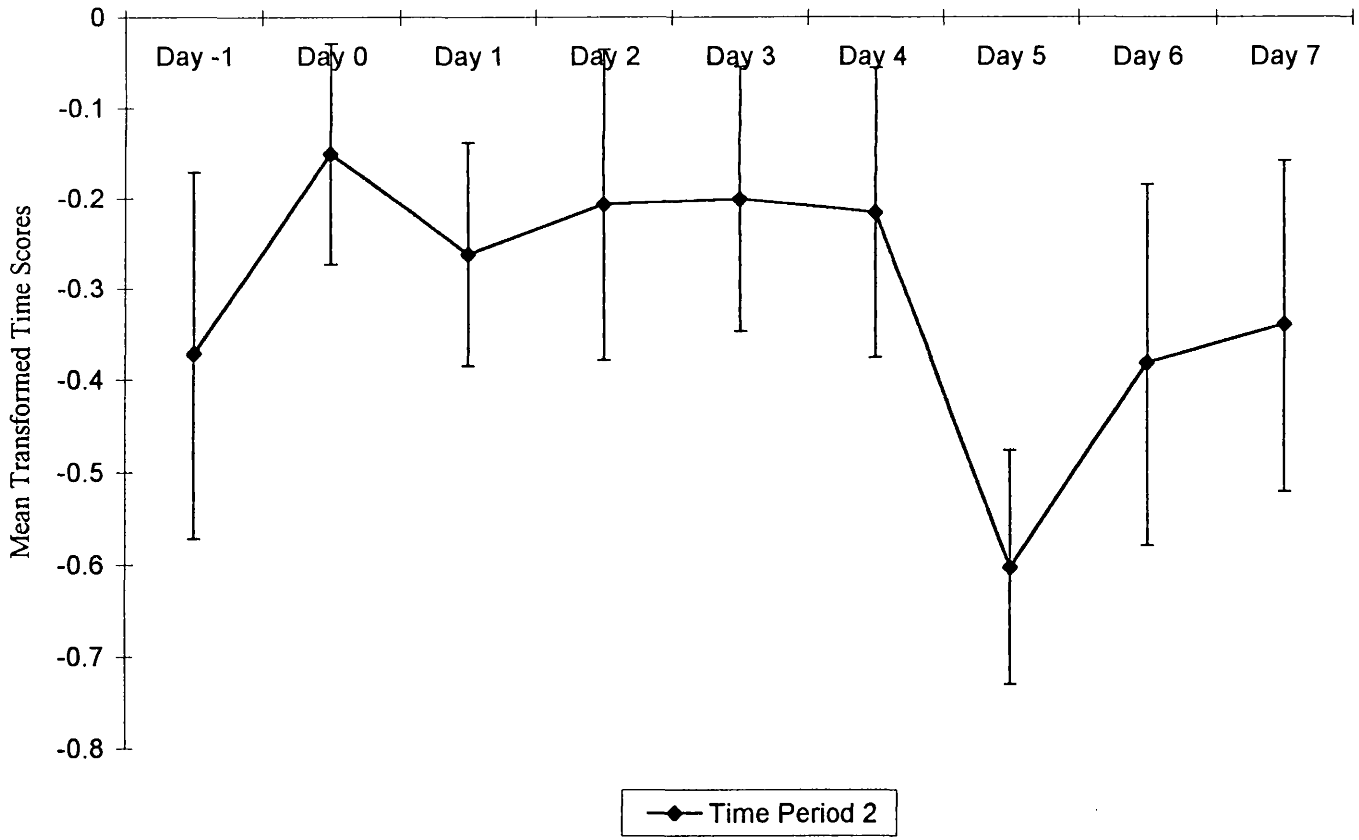


Figure 7 **Plot of Mean Transformed Time Scores by Day Number for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 in Time Period 3 across all trips**

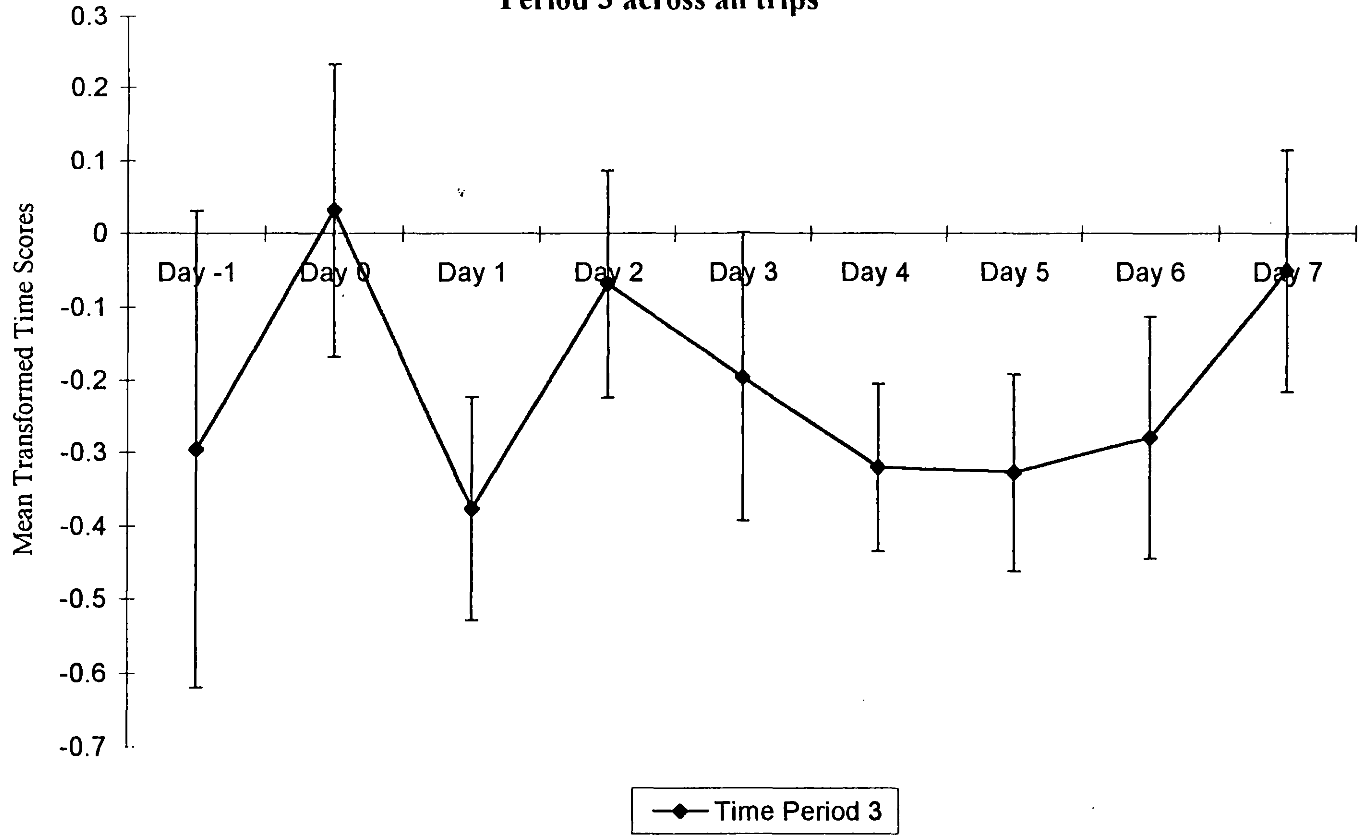


Figure 8 **Plot of Mean Transformed Time Scores by Day Number for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 in Time Period 4 across all trips**

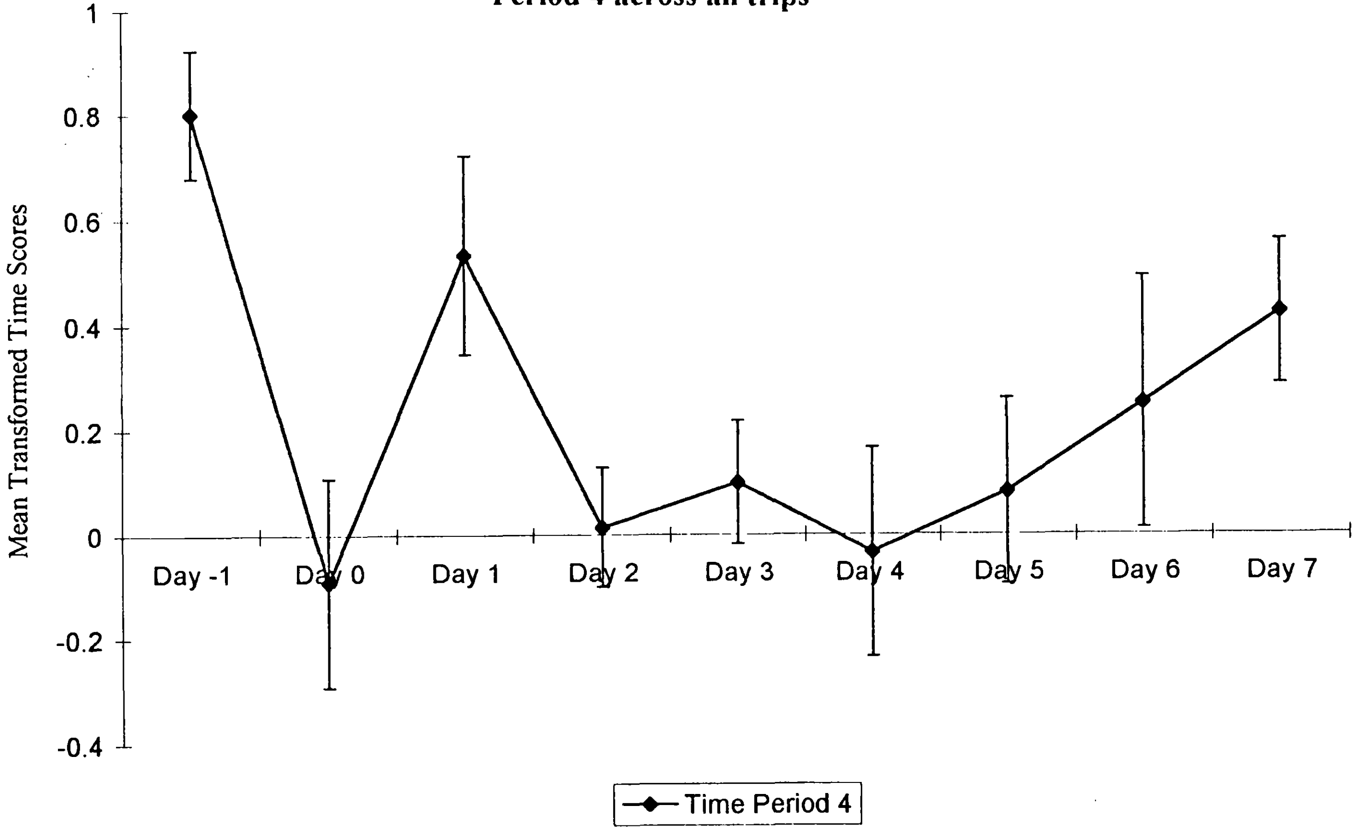


Figure 9 Plot of Mean Transformed Time Scores by Time Period for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed in Time Periods 1 to 4 on each of Days -1, 0, 1, 2, 3, 4, 5, 6 and 7 across all trips

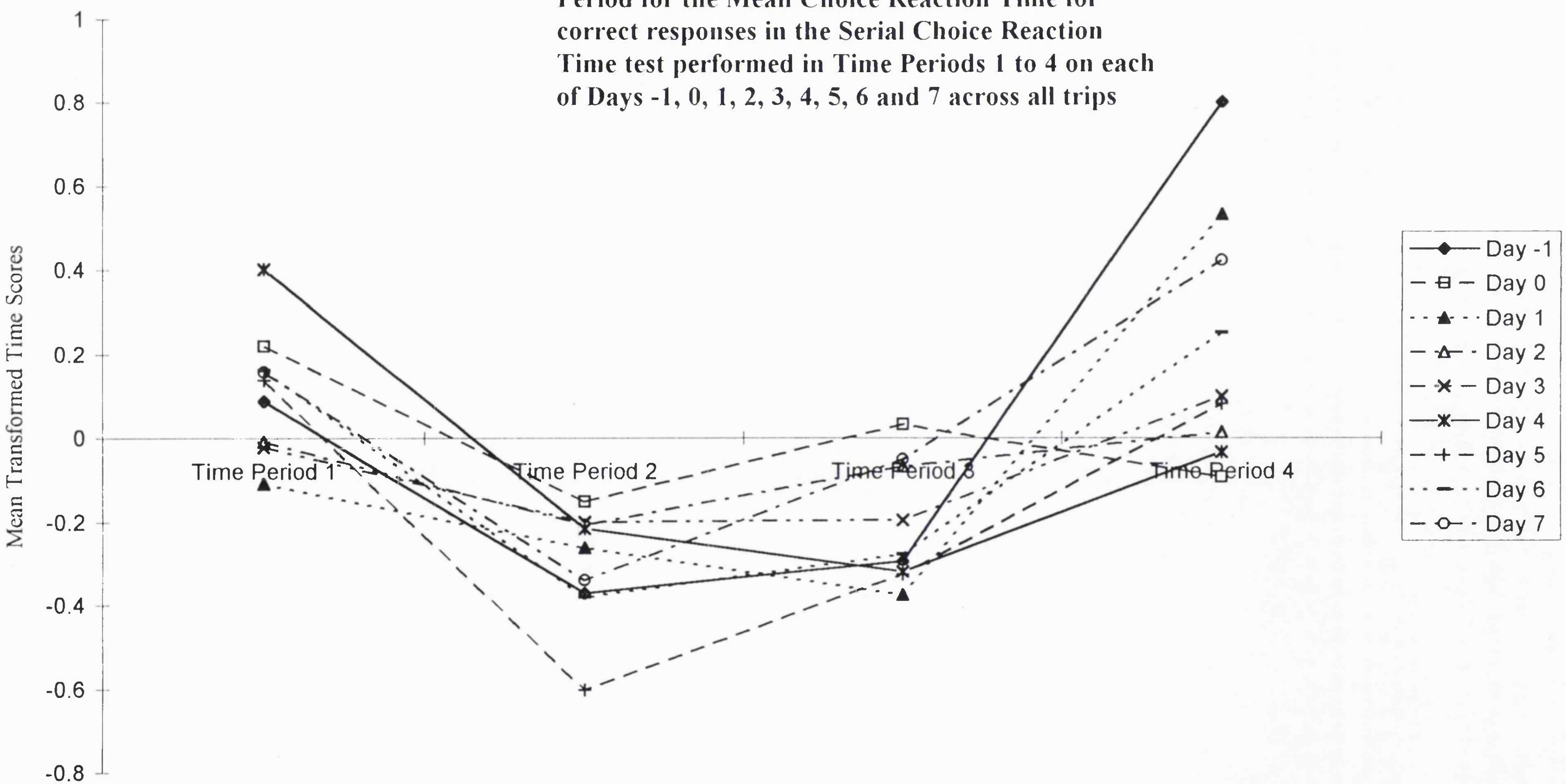
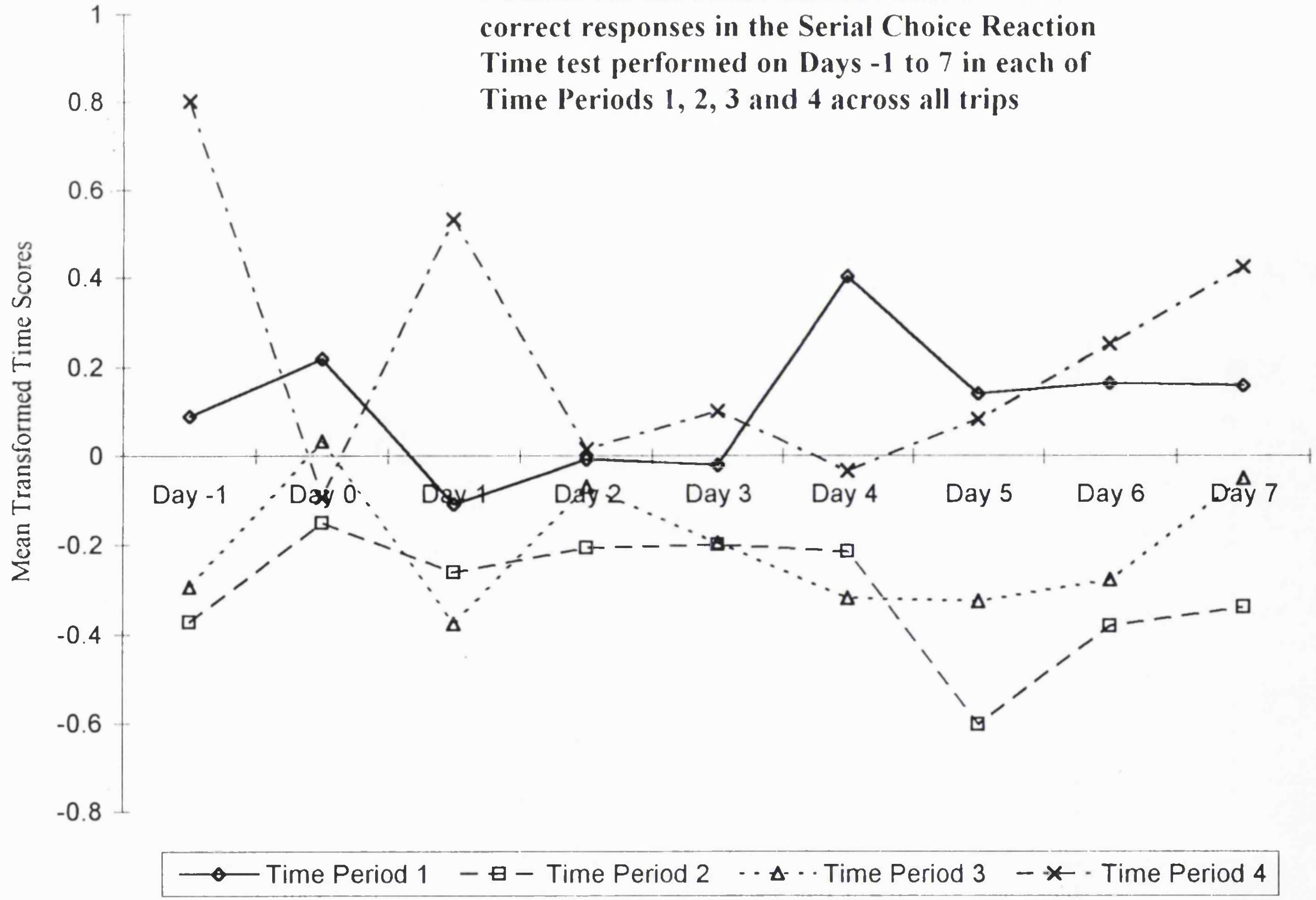


Figure 10 **Plot of Mean Transformed Time Scores by Day Number for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 in each of Time Periods 1, 2, 3 and 4 across all trips**



4.8

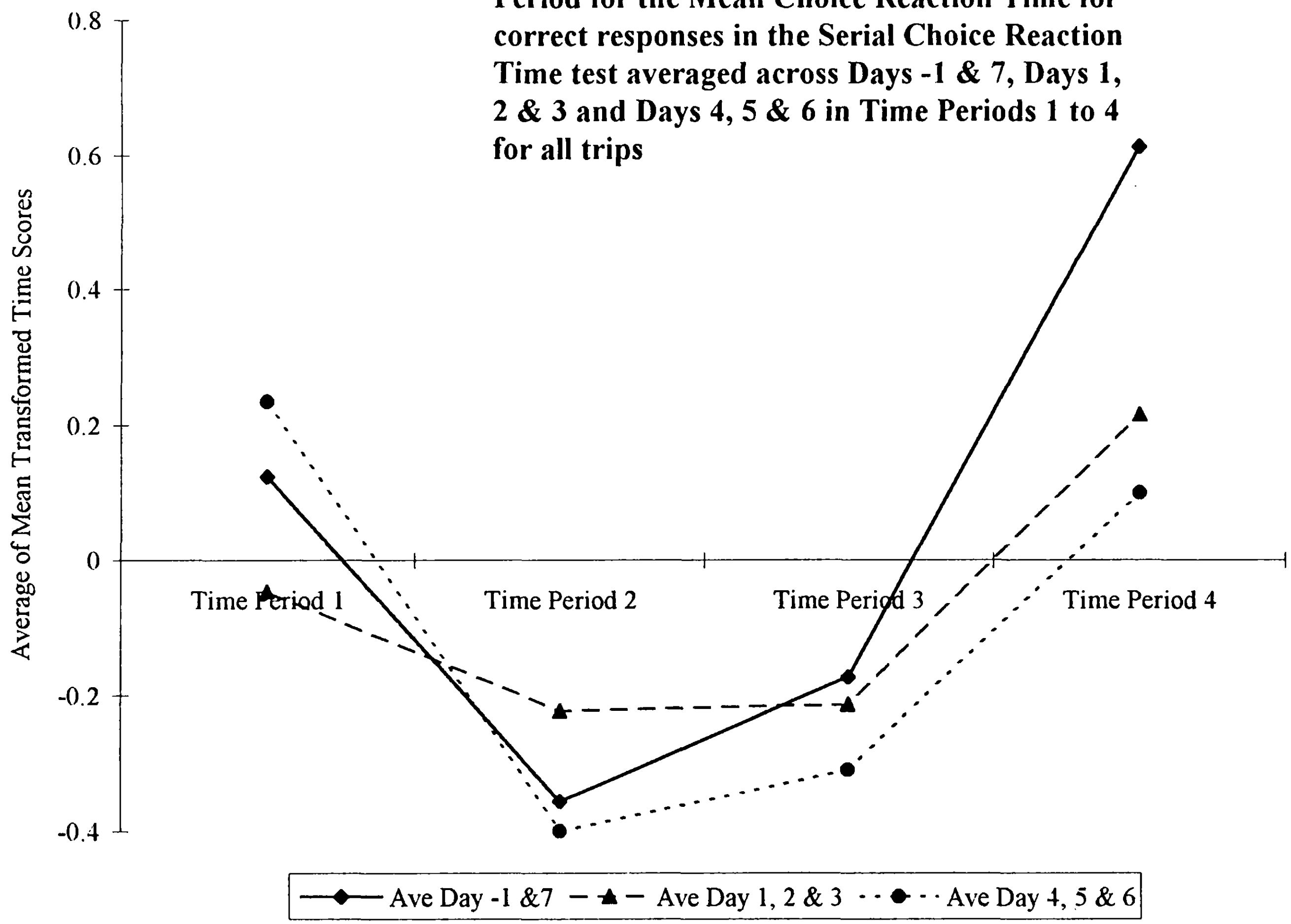
In an attempt to further identify the exact nature of the Day*Time interaction, Table 99 divides the overall day span (Day -1 to Day 7) into 3 smaller sub-spans with the Mean Transformed Time Scores averaged within each one. The 3 sub-spans employed are based on the findings in Figure 10 where it would appear that the Day*Time interaction fully resolves by Day 7 and the pre-trip ranking pattern of the Time Periods is restored. An average of the scores obtained in Days -1 and 7 is therefore used as a base-line and the intervening 6 days divided into 2 equal sub-spans, representing the early part of the trip (Days 1, 2 and 3) and the latter part of the trip (Days 4, 5 and 6).

Table 99 - Table of Mean Transformed Time Scores for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test averaged across Days -1 & 7, Days 1, 2 & 3 and Days 4, 5 & 6 in Time Periods 1 to 4 for all trips

	Average of Mean Transformed Time Scores		
Time Period	Days -1 & 7	Days 1, 2 & 3	Days 4, 5 & 6
1	0.123	-0.047	0.234
2	-0.356	-0.223	-0.400
3	-0.173	-0.214	-0.309
4	0.612	0.215	0.099

The results are shown graphically in Figure 11 and demonstrate that the Day*Time interaction involves all 3 sub-spans between Time Periods 1 and 2, but only the sub-spans covering the early portion of the trip between Time Periods 2 and 3. However, despite this the overall broad pattern is sustained with faster results in Time Periods 2 and 3 across the entire day span.

Figure 11 **Plot of Mean Transformed Time Scores by Time Period for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test averaged across Days -1 & 7, Days 1, 2 & 3 and Days 4, 5 & 6 in Time Periods 1 to 4 for all trips**



4.8

Table 100- Table of ranked Mean Transformed Trip Scores for the Mean Choice Reaction Time for correct responses in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Trip Scores	No. of Observations contributing to Mean	Trip Number
0.10	335	2
0.04	194	5
-0.01	383	1
-0.06	314	3
-0.08	270	4

Table 100 represents the ranked Mean Transformed Trip Scores obtained after carrying out a 3-way Analysis of Variance including trip as a factor. As indicated in the introduction, following removal of the practice effect, a Trip effect is unlikely and this is borne out by a non-significant main effect ($F(4,1317) = 1.67$; $Pr > F = 0.1556$) and no comparison significant under the REGW test.

Analyses for the Transformed Percentage Accuracy data are shown in Tables 101 to 104.

4.8

Table 101 - Table of Day Effect, Time Effect and Day*Time interaction for the Transformed Percentage Accuracy in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Principal Effect/ Interaction	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Pr > F
Day	8	22.10	2.76	2.79	0.0046
Time of Day	3	13.70	4.57	4.61	0.0032
Day*Time	24	21.77	0.91	0.92	0.5814

Table 101 shows the presence of both a Day and Time of Day effect. As before, further ranked analyses were performed and are shown in Tables 102 to 104.

4.8

Table 102 - Table of ranked Mean Transformed Day Scores for the Transformed Percentage Accuracy in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Day Scores	No. of Observations contributing to Mean	Day Number
0.20	150	1
0.20	117	-1
0.15	166	0
0.14	186	3
0.06	170	5
0.05	149	7
0.00	192	2
-0.11	185	4
-0.12	181	6

Individual pair-wise day comparisons show no significant difference between the Day scores. However, the Ryan-Einot-Gabriel-Welsch multiple range test does take account of multiple comparisons and this therefore explains the contradiction with the overall Day Effect indicated in Table 101.

Unlike the Mean Choice Reaction Time, positive values for the Transformed Percentage Accuracy indicate better performance and negative values poorer performance. It is therefore clear that the base-line score for Day -1 is the same as that obtained on Day 1 and reinforces the indication from Table 96 that the pre-trip score is not significantly different from later values.

4.8

Table 103 - Table of ranked Mean Transformed Time Scores for the Transformed Percentage Accuracy in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Time Scores	No. of Observations contributing to Mean	Time Period
0.14	565	1
0.12	350	2
-0.07	255	3
-0.08	326	4

The Ryan-Einot-Gabriel-Welsch multiple range test confirms that results from Time Periods 1 and 2 are significantly better than those from Time Periods 3 and 4 respectively. This together with the values for the Mean Choice Reaction Time implies that in Time Period 2 (10^{00} - 15^{59}) subjects are fastest and are also more accurate than in Time Periods 3 and 4 whereas in Time Period 1 (before 10^{00}) their reaction time is slower, but their accuracy is greatest. Time Period 4 (after 20^{00}), as may be expected yields results that are both slowest and least accurate.

Table 104 shows the Transformed Trip Scores which are non-significant, backing up the main effect finding ($F(4,1317) = 0.42$; $Pr > F = 0.7910$).

4.8

Table 104 - Table of ranked Mean Transformed Trip Scores for the Transformed Percentage Accuracy in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Trip Scores	No. of Observations contributing to Mean	Trip Number
0.10	335	2
0.05	270	4
0.04	314	3
0.04	194	5
0.03	383	1

Similar analyses were performed for the Transformed Number of Gaps.

Table 105 - Table of Day Effect, Time Effect and Day*Time interaction for the Transformed Number of Gaps in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Principal Effect/ Interaction	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Pr > F
Day	8	6.82	0.85	0.79	0.6074
Time of Day	3	3.18	1.06	0.99	0.3982
Day*Time	24	25.44	1.06	0.99	0.4801

Table 105 does not indicate the presence of a Day or Time of Day effect, or Day*Time interaction. However, for completeness, Tables 106 to 108 represent the ranked data for Transformed Day, Time and Trip scores, which, as expected, do not show any differences and with respect to the Transformed Trip score, support the main effect finding ($F(4,1317) = 0.58$; $Pr > F = 0.6795$).

However, Table 107 does appear to show that there are less Gaps during Time Period 3 than Time Period 4 indicating that the results obtained in Time Period 4 are slower, least accurate and with most Gaps, although none of the differences are statistically significant.

Table 106 - Table of ranked Mean Transformed Day Scores for the Transformed Number of Gaps in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Day Scores	No. of Observations contributing to Mean	Day Number
0.13	150	1
0.06	192	2
0.06	185	4
0.02	181	6
-0.01	186	3
-0.02	166	0
-0.05	149	7
-0.07	170	5
-0.12	117	-1

4.8

Table 107 - Table of ranked Mean Transformed Time Scores for the Transformed Number of Gaps in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Time Scores	No. of Observations contributing to Mean	Time Period
0.09	326	4
0.00	565	1
-0.03	350	2
-0.04	255	3

Table 108 - Table of ranked Mean Transformed Trip Scores for the Transformed Number of Gaps in the Serial Choice Reaction Time test performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Trip Scores	No. of Observations contributing to Mean	Trip Number
0.05	194	5
0.04	314	3
0.00	383	1
-0.01	335	2
-0.06	270	4

4.8

<u>Memory Search Task</u>

An identical series of analyses were also performed on the data obtained for the Mean Correct Response Time and the Transformed Proportion of Correct Responses in the modified Sternberg Memory Search Task, see Tables 109 to 118.

Table 109 - Table of Day Effect, Time Effect and Day∗Time interaction for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Principal Effect/ Interaction	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Pr > F
Day	8	3.28	0.41	0.40	0.9210
Time of Day	3	11.40	3.80	3.71	0.0112
Day∗Time	24	48.29	2.01	1.96	0.0036

Table 109 indicates that there is no apparent Day effect but there is nevertheless a significant Time of Day effect and highly significant Day∗Time interaction. Examining these in more detail.

4.8

Table 110 - Table of ranked Mean Transformed Day Scores for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Day Scores	No. of Observations contributing to Mean	Day Number
0.03	149	7
0.00	185	4
-0.01	150	1
-0.02	166	0
-0.03	192	2
-0.03	170	5
-0.07	186	3
-0.07	181	6
-0.13	116	-1

As with the reaction time in the Serial Choice Reaction Time test, positive values indicate worsening performance and negative values better performance and applying the Ryan-Einot-Gabriel-Welsch multiple range test to the results confirms that no pair-wise day comparisons are significant.

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Table 111 - Table of ranked Mean Transformed Time Scores for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Time Scores	No. of Observations contributing to Mean	Time Period
0.05	566	1
-0.01	329	4
-0.07	252	3
-0.18	348	2

From the data in Table 111 however, there is a significant pair-wise comparison between Time Period 1 and Time Period 2, which, like the Mean Choice Reaction Time in the Serial Choice Reaction Time test, indicates that the results obtained in Time Period 2 are fastest. In this case however, those obtained in Time Period 1 are the slowest, see Figure 12 overleaf.

The same relationship as above is found if Time Period 4 is omitted from the analysis. The Analysis of Variance model provides a statistically significant fit ($F(26,1139) = 1.86$; $Pr > F$ 0.0057) with the ranked Transformed Time scores likewise demonstrating that the results obtained in Time Period 2 are fastest and those in Time Period 1 slowest, the difference being significant at the 5% level. This confirms that there is nothing to be gained by omitting Time Period 4 from the analyses unless there is a requirement to examine the day differences irrespective of Time Periods.

Figure 12 **Plot of the overall Mean Transformed Time Scores by Time Period for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips**

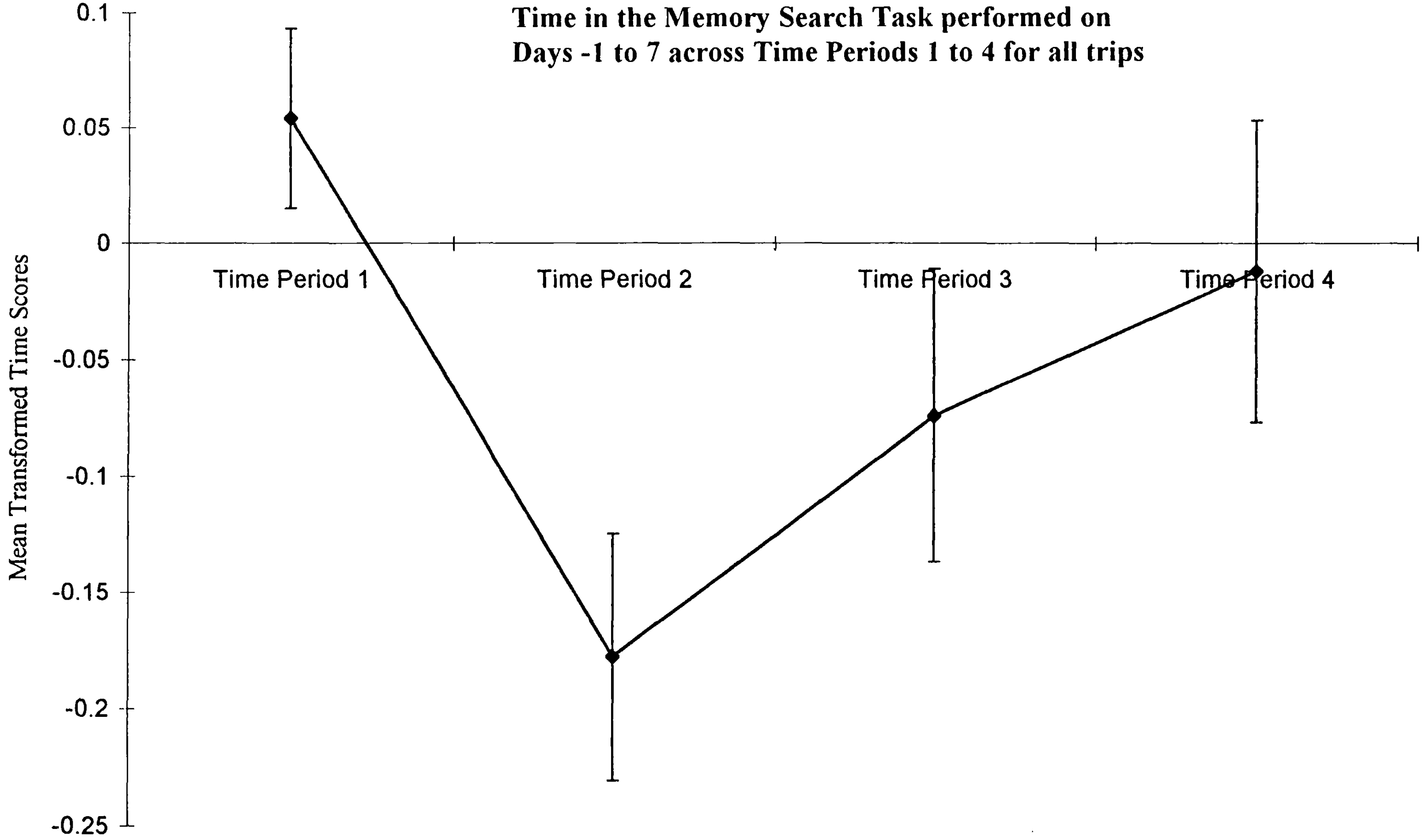

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Table 109 also demonstrates that there is a highly significant Day∗Time interaction indicating that, when ranking the Transformed Time scores, the ranking sequence differs on each day.

The Transformed Time Scores for each Day Number and Time Period are shown in Table 112 and again in Figures 13, 14, 15, 16, 17 and 18. Figures 17 and 18 summarise the findings and demonstrate an overall improvement in Mean Correct Response Time in Time Periods 3 and 4 over Days -1, 1, 2 and 3 resulting in an inversion of the ranking pattern for the Time Periods such that from Day 3 to Day 6, the response time in Time Period 2 is slower than that in both Time Periods 3 and 4 although the difference is within the limits of the standard errors calculated.

4.8

Table 112 - Table of Mean Transformed Time Scores for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 in each of Time Periods 1, 2, 3 and 4 across all trips

Day Number	Time Period	No. of Observations contributing to Mean	Mean Transformed Time Scores	Standard Error
-1	1	35	-0.25	0.14
-1	2	32	-0.73	0.20
-1	3	15	0.20	0.33
-1	4	34	0.41	0.15
0	1	63	0.00	0.11
0	2	54	-0.08	0.11
0	3	25	-0.20	0.20
0	4	24	0.25	0.20
1	1	41	0.01	0.17
1	2	36	-0.45	0.12
1	3	32	0.15	0.19
1	4	41	0.22	0.19
2	1	73	0.00	0.12
2	2	43	-0.09	0.12
2	3	38	0.09	0.16
2	4	38	-0.15	0.14
3	1	75	0.04	0.10
3	2	40	0.00	0.20
3	3	26	-0.21	0.21
3	4	45	-0.25	0.13
4	1	73	0.30	0.12
4	2	42	-0.14	0.14
4	3	31	-0.23	0.15
4	4	39	-0.23	0.25
5	1	75	0.05	0.12
5	2	29	0.03	0.18
5	3	29	-0.21	0.16
5	4	37	-0.12	0.21
6	1	69	0.15	0.11
6	2	42	-0.18	0.18
6	3	29	-0.28	0.20
6	4	41	-0.21	0.26
7	1	62	0.01	0.09
7	2	30	-0.07	0.20
7	3	27	0.05	0.19
7	4	30	0.18	0.15

Figure 13 Plot of Mean Transformed Time Scores by Day Number for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 in Time Period 1 across all trips

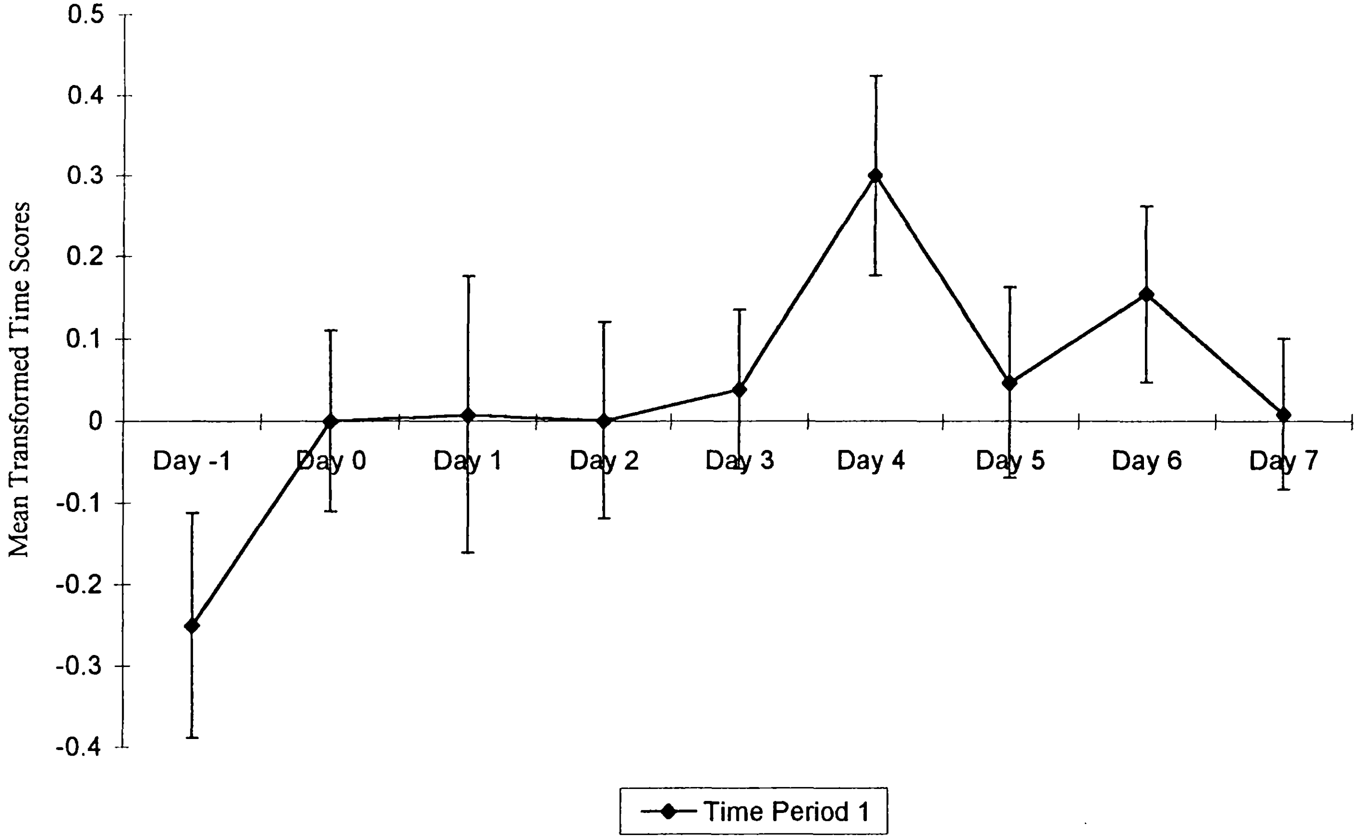


Figure 14 **Plot of Mean Transformed Time Scores by Day Number for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 in Time Period 2 across all trips**

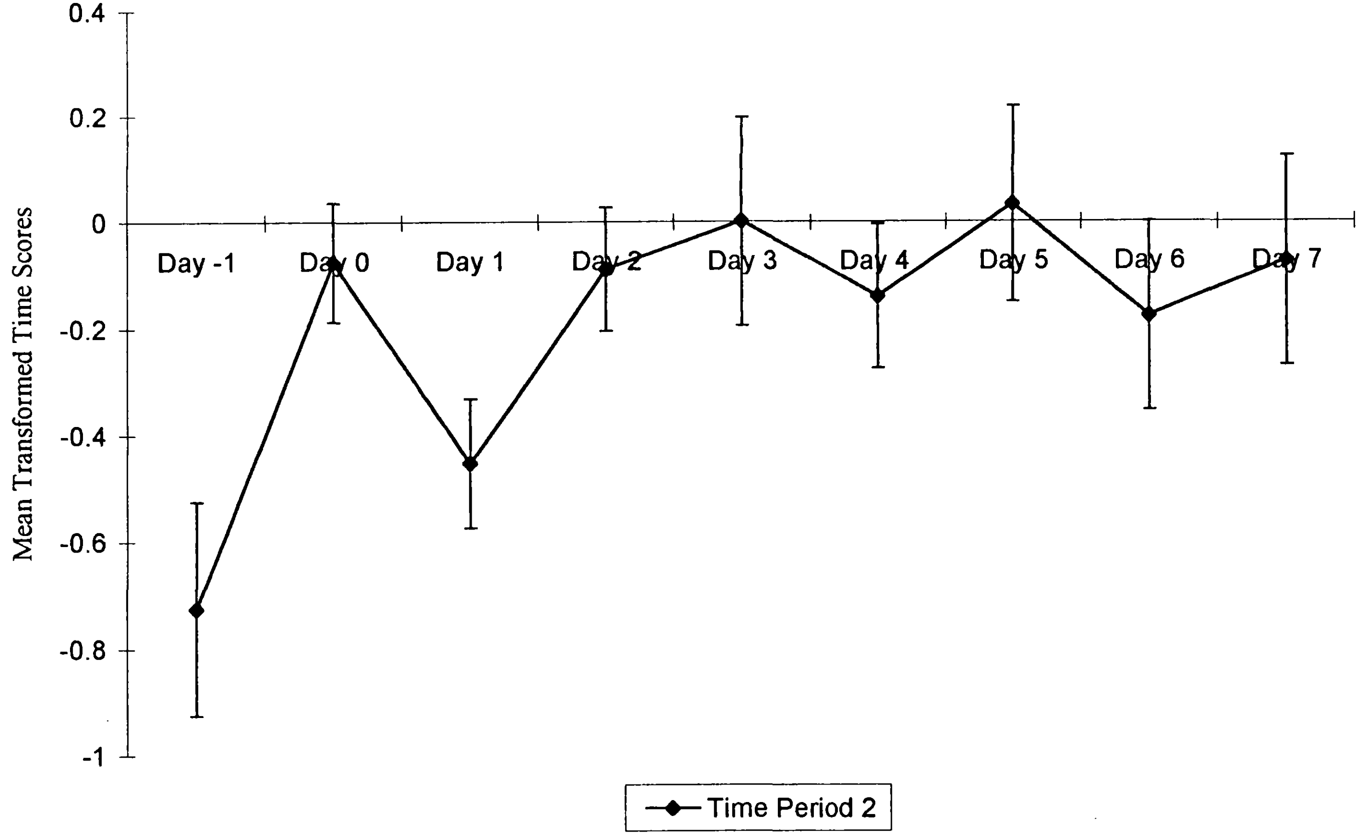


Figure 15 **Plot of Mean Transformed Time Scores by Day Number for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 in Time Period 3 across all trips**

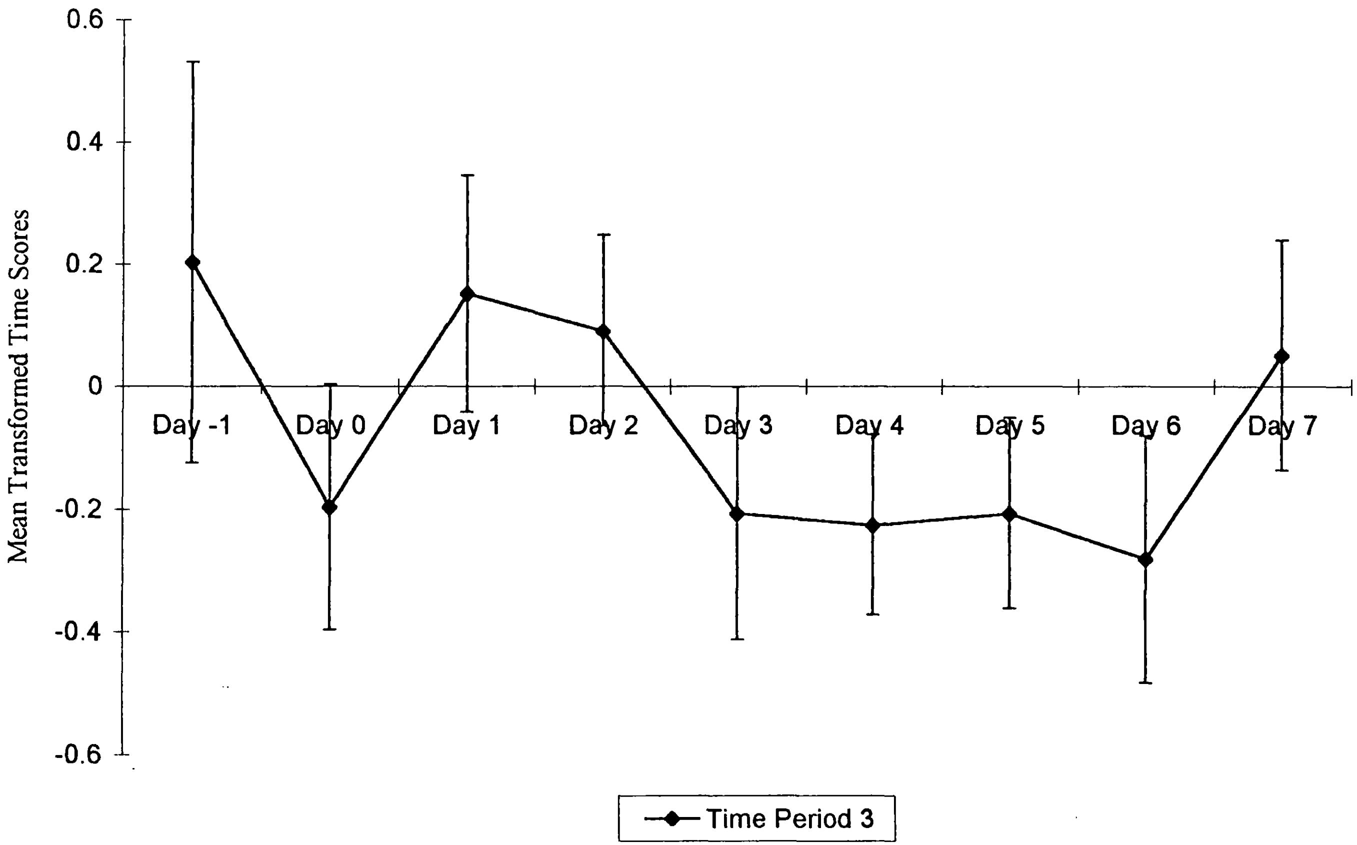


Figure 16 Plot of Mean Transformed Time Scores by Day Number for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 in Time Period 4 across all trips

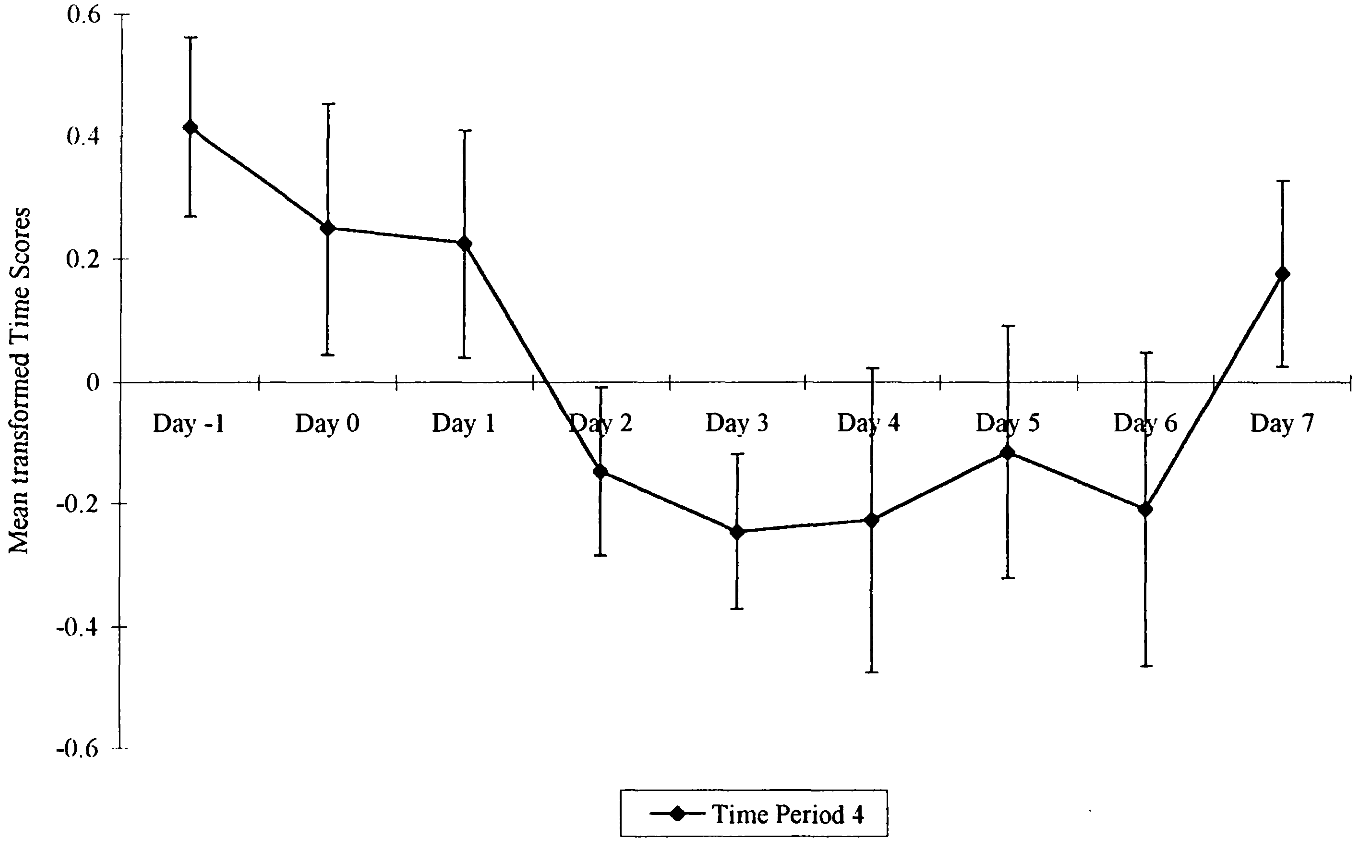


Figure 17 **Plot of Mean Transformed Time Scores by Time Period for the Mean Correct Response Time in the Memory Search Task performed in Time Periods 1 to 4 on each of Days -1, 0, 1, 2, 3, 4, 5, 6 and 7 across all trips**

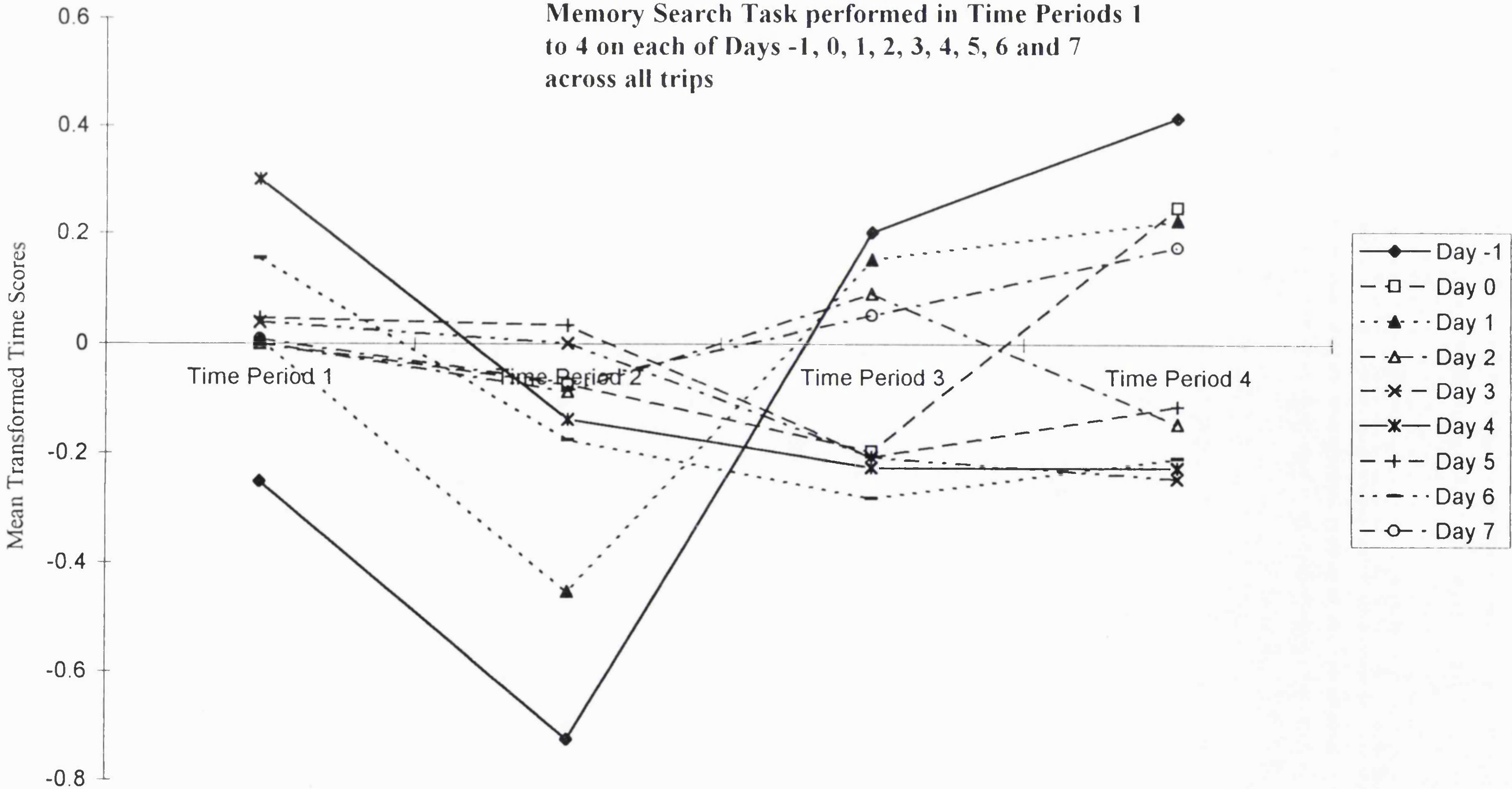
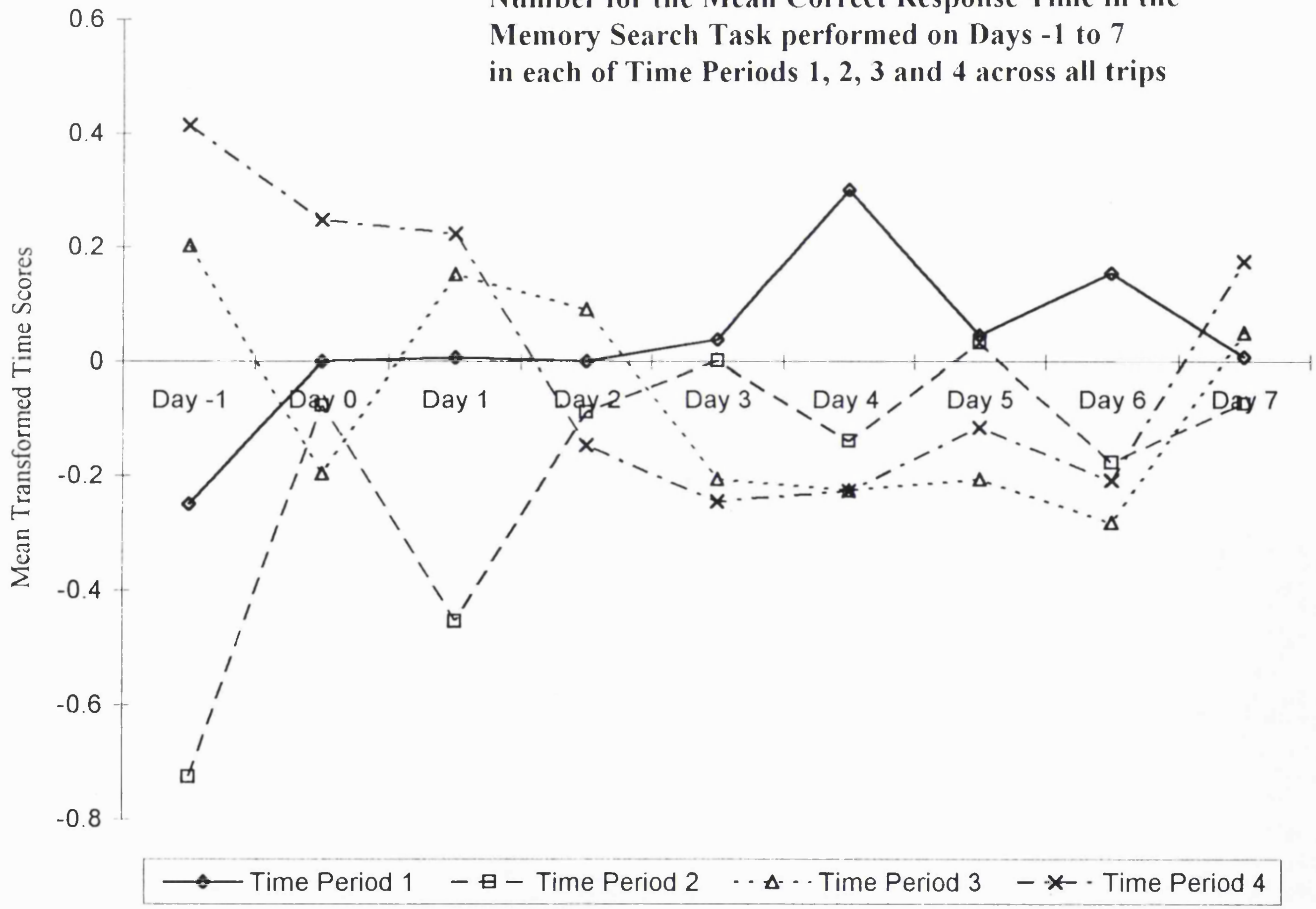


Figure 18 Plot of Mean Transformed Time Scores by Day Number for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 in each of Time Periods 1, 2, 3 and 4 across all trips



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As with the results for the Serial Choice Reaction Time test, the overall day span has once again been divided into 3 smaller sub-spans in an attempt to further clarify the nature of the Day∗Time interaction. The results are shown in Table 113 and Figure 19 and clearly demonstrate that the Mean Correct Response Time is fastest in Time Period 2 during the base-line day span and early part of the trip and that this pattern subsequently changes such that the Mean Correct Response Time becomes fastest in Time Period 3 during the sub-span Day 4 to 6.

It is clear that the overall amplitude of the performance variation for both tests is diminished over the complete span Day 1 to Day 6. In addition, when comparing the shape of Figure 17 to that of Figure 9, it is apparent that the speed of response peaks earlier in the day for the Memory Search Task than for the Serial Choice Reaction Time.

Table 113- Table of Mean Transformed Time Scores for the Mean Correct Response Time in the Memory Search Task averaged across Days -1 & 7, Days 1, 2 & 3 and Days 4, 5 & 6 in Time Periods 1 to 4 for all trips

	Average of Mean Transformed Time Scores		
Time Period	Days -1 & 7	Days 1, 2 & 3	Days 4, 5 & 6
1	-0.122	0.015	0.167
2	-0.400	-0.181	-0.095
3	0.127	0.012	-0.238
4	0.295	-0.057	-0.184

Figure 19 **Plot of Mean Transformed Time Scores by Time Period for the Mean Correct Response Time in the Memory Search Task averaged across Days -1 & 7, Days 1, 2 and 3 and Days 4, 5 and 6 in Time Periods 1 to 4 for all trips**

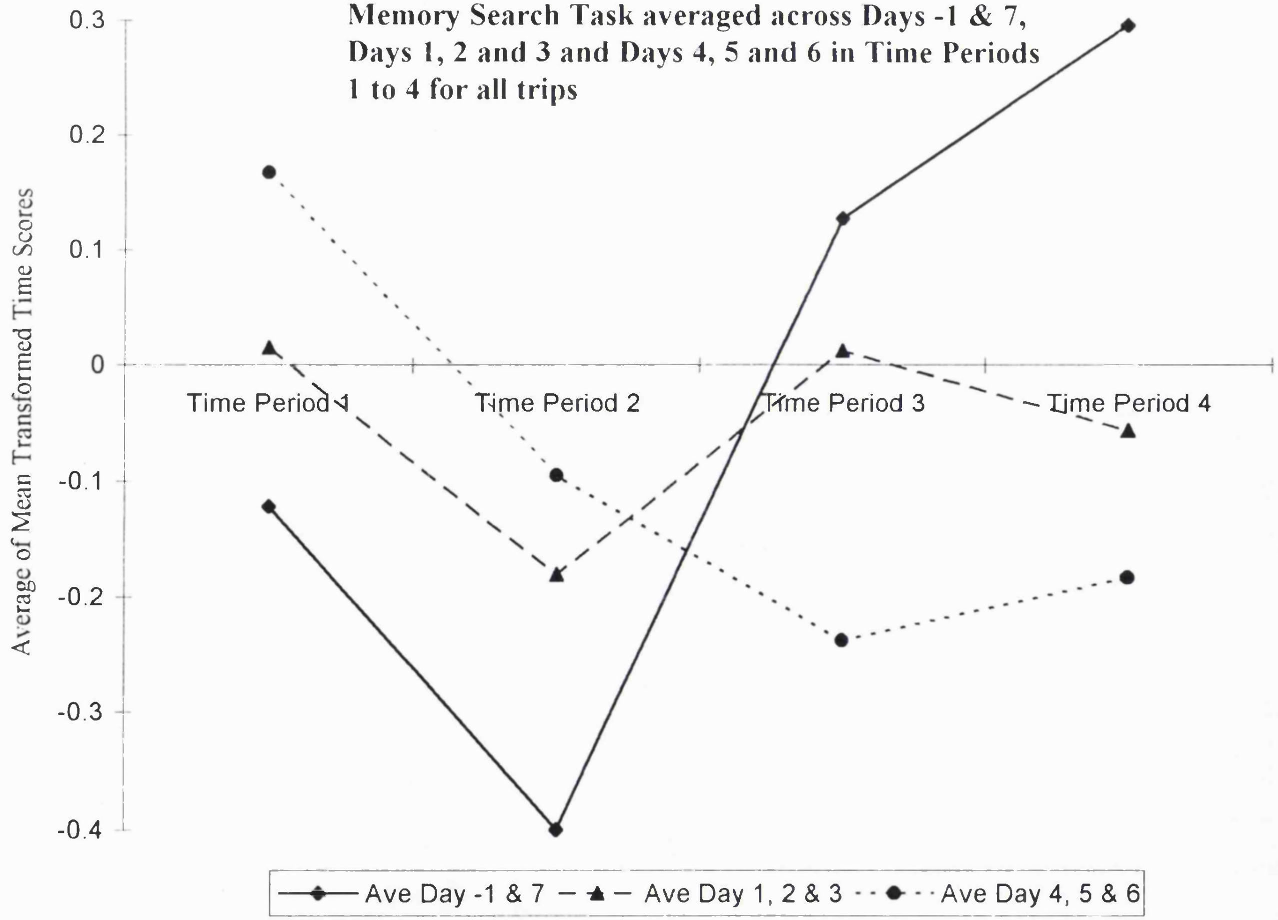

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Table 114 - Table of ranked Mean Transformed Trip Scores for the Mean Correct Response Time in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Trip Scores	No. of Observations contributing to Mean	Trip Number
0.02	269	4
-0.01	383	1
-0.06	335	2
-0.07	314	3
-0.07	194	5

The overall Trip effect was non-significant ($F(4,1316) = 0.60$; $Pr > F = 0.6595$) and although Table 114 indicates that there may be a suggestion of improvement in Mean Correct Response Time across the 5 Trips, the results from Trip 4 are contradictory and none reach statistical significance.

Finally, turning to the results obtained for the Transformed Proportion of Correct Responses, Table 115 does not indicate the presence of a Day, Time of Day effect or Day∗Time interaction.

4.8

Table 115 - Table of Day Effect, Time Effect and Day∗Time interaction for the Transformed Proportion of Correct Responses in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Principal Effect/ Interaction	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Pr > F
Day	8	3.80	0.47	0.45	0.8931
Time of Day	3	2.62	0.87	0.82	0.4811
Day∗Time	24	20.34	0.85	0.80	0.7429

More detailed examination by ranking the Transformed Day, Time and Trip scores and applying the Ryan-Einot-Gabriel-Welsch multiple range test confirms the absence of any pair-wise Day, Time of Day or Trip Effects, see Tables 116 to 118.

4.8

Table 116 - Table of ranked Mean Transformed Day Scores for the Transformed Proportion of Correct Responses in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Day Scores	No. of Observations contributing to Mean	Day Number
0.12	192	2
0.04	116	-1
0.03	166	0
0.02	149	7
0.01	181	6
0.00	185	4
-0.01	186	3
-0.02	150	1
-0.07	170	5

Table 117 - Table of ranked Mean Transformed Time Scores for the Transformed Proportion of Correct Responses in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Time Scores	No. of Observations contributing to Mean	Time Period
0.05	348	2
0.04	566	1
-0.02	252	3
-0.05	329	4

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In the case of the Transformed Proportion of Correct Responses, positive values indicate an improvement in accuracy and negative values a decline. Thus, although not statistically significant using the Ryan-Einot-Gabriel-Welsch multiple range test, results presented in Table 117 show that Memory Search Tasks performed in Time Period 2 are the most accurate. This, together with the results from Table 111, indicate that test sequences performed in Time Period 2 are both fastest and most accurate.

Finally, turning to the Trip Effect, see Table 118.

Table 118 - Table of ranked Mean Transformed Trip Scores for the Transformed Proportion of Correct Responses in the Memory Search Task performed on Days -1 to 7 across Time Periods 1 to 4 for all trips

Mean Transformed Trip Scores	No. of Observations contributing to Mean	Trip Number
0.05	335	2
0.03	383	1
0.02	194	5
-0.02	314	3
-0.02	269	4

There are no significant pair-wise comparisons which consolidates the non-significant main effect finding ($F(4,1316) = 0.12$; $Pr > F = 0.9748$).

In summary therefore, the Analysis of Variance method of analysis, following polynomial de-trending and Z-score transformation, has, unlike the Repeated Measures Analysis of Variance, provided a number of statistically significant

4.8

results for the tests of cognitive performance both before and after long haul transmeridian flights.

With respect to the Serial Choice Reaction Time test, task sequences performed in Time Period 2 appear to be fastest (as measured by the Mean Choice Reaction Time) and are also more accurate than those in Time Periods 3 and 4 (as measured by the Transformed Percentage Accuracy). In addition, there is a significant Day∗Time interaction for the Mean Choice Reaction Time, but no evidence of either a Day or Trip effect for either parameter or indeed evidence of any effect for the Transformed Number of Gaps.

As far as the Memory Search Task is concerned, only the Mean Correct Response Time shows any significant effect with the results obtained in Time Period 2 being the fastest. There is also a highly significant Day∗Time interaction with inversion of the pre-trip ranking pattern for Time Periods between Days 3 and 6. There are however, no other Day, Time of Day, or Trip effects apparent.

SECTION 5

DISCUSSION

5.1 PHASE 1 - TRAVELLER PROFILE STUDY - DISCUSSION

The Phase 1 - Traveller Profile Study was questionnaire based with the aim of identifying those individuals likely to suffer from significant effects of travel fatigue in advance of their first transmeridian flight. As part of the questionnaire, two self-report instruments were employed, the Circadian Type Inventory (CTI) (Folkard 1987) and the Composite Morningness Questionnaire (CMQ) (Smith 1989). Recruitment was volunteer based and it is therefore entirely fortuitous that the subject population provided the spectrum of ages, sex and travel experience necessary to enable a worthwhile analysis to be undertaken.

The data obtained for males and females yielded no difference in the perception of travel fatigue between the sexes, with the exception that males tended to recall that their appetite and mental alertness were more affected. It is possible this was due to the male population having travelled more frequently in the preceding five years compared to females. However, if experience alone was considered as a variable, those subjects who had completed ten or more long haul trips appeared to suffer from the effects of transmeridian travel fatigue to much the same extent as less experienced travellers. However, with flights in a northerly or southerly direction, experienced travellers appeared to suffer less than those who were inexperienced. This is not unexpected, as north/south travel does not involve significant time changes and therefore circadian desynchronosis is less of a factor. However, travellers will nonetheless be fatigued as a result of the journey itself, which may or may not involve the loss of a night's sleep, although these symptoms should resolve rapidly following arrival at the destination (Monk 1987). Greater experience of transmeridian travel did not appear to result in a lower perception of travel fatigue as may be expected despite the "favoured practices" that were developed by regular travellers in order to minimise their symptoms (see Appendix VII). It is well known that individuals vary in the amplitude and stability of their circadian rhythms and there are a number of self-report instruments which attempt to measure these differences. Three of these have been used in this study and their origins are outlined in Section 3.3 Phase 1 - Traveller Profile Study - Method.

The Circadian Type Inventory (CTI) (Folkard 1987) consists of two scales; Languidness/Vigorousness and Flexibility/Rigidity. Vigorousness is conceptualised as an ability to overcome drowsiness and rigidity as the inability to sleep at unusual times, in other words, the subject has rigid sleeping habits (Folkard 1979b).

The Composite Morningness Questionnaire (CMQ) (Smith 1989) was the second instrument employed in this study and appears to be superior to previous scales such as Horne and Ostberg's Eveningness/Morningness scale (1976). However, as with all self-report instruments of this type it is based on a set of questions judged to be of some importance in determining an individual's ability to adjust their circadian rhythms, although, as may be expected, these judgements are subjective and guided by the hypothesis that better adjustment may be shown by individuals with:

a) low amplitude rhythms, and
b) "flexible" or "non stable" rhythms (Folkard 1979b)

Unfortunately, although this is a reasonable working hypothesis, psychometric evaluation of the CTI based on a study of 191 students (Smith 1993) indicates that it fails to achieve close mapping of circadian rhythm characteristics on to questionnaire scales. The reliability of the internal sub-scales of the CTI is not good (Smith 1993) but it is nonetheless the best predictor of long term suitability for shift work (Iskra-Golec 1993) and it is clear that certainly, for identifying long term problems with shift work, the vigorousness scale correlates with 4 out of 5 "health problems" after three years on shifts (Vidacek 1987).

Smith's psychometric evaluation (1993) was published after the commencement of this study, but, as the overall effect of travel fatigue comprises more than just circadian desynchronisation, it was decided to continue with the Traveller Profile Study using both the CTI and CMQ to examine whether subjective ratings of travel fatigue correlate with personality type as defined by these measures.

There was no indication of any apparent differences between males and females with regard to their Languidness/Vigorousness, Flexibility/Rigidity or Eveningness/Morningness scores thus reinforcing the underlying argument that both genders can be similarly characterised in terms of circadian type (Webb 1981).

The results of the study identified a limited number of factors which alter as ages increases. In particular, it was seen that the Languidness/ Vigorousness score decreased and the Eveningness/Morningness score increased with age indicating that as individuals get older, they become more able to overcome drowsiness, although exhibiting more characteristics of morning types. However, although these correlations were statistically significant, the correlation coefficients were low and indicated that age accounted for only 8% and 6% of the variance respectively in the Languidness/Vigorousness and Eveningness/Morningness scores.

5.1

In addition, it is predicted that an individual who scores highly on the vigorousness scale is able to miss a night's sleep, to be relatively unaffected by lack of sleep and to be able to wake up easily at unusual times. This does not fit comfortably with our knowledge of the effect of age on sleep patterns, and indeed, Folkard (1979b) found no significant correlation between vigorousness and age.

On the other hand, it is well known that individuals exhibit more morning characteristics as they get older, and, in line with the findings of this study, Gander (1993) concluded that for flight crew, age alone may account for up to 8% of the variance in the Eveningness/Morningness score.

With regard to alcohol, the majority of respondents (79 out of 100) indicated that they consumed alcohol on board the aircraft. This preponderance of "drinkers" must be borne in mind when considering the results comparing their perception of travel fatigue with "non-drinkers". It would appear that "non-drinkers" suffer more significant effects of travel fatigue when travelling south compared to "drinkers". However, experience of travel in this direction was limited in the population under consideration and involved only 48 "drinkers" and 14 "non-drinkers", with a difference only nominally significant at the 5% level.

The only other factor which approached significance was the additional symptoms of travel fatigue such as headache reported by some individuals which appeared to be greater in "non-drinkers". However, the numbers in this category were even smaller and based on only 11 "drinkers" and 4 "non-drinkers" making it impossible to come to any firm conclusions.

5.1

A similar situation was encountered when examining the effect of napping. Of 100 subjects, only 13 admitted to napping and there was no apparent difference in the perception of travel fatigue between those who napped and those who did not. Unfortunately, the question "Do you nap during the day? Yes/No" was not sufficiently discriminatory with the small numbers involved and the results do not help in identifying whether napping decreases the overall sleep requirement or reduces the perceived severity of travel fatigue. Indeed, it is likely that the main benefit of napping is connected with reducing the period of prolonged wakefulness and attenuating the extent of the deterioration in performance rather than in mood parameters (Dinges 1988).

Assessment of the personality type indicated that there was some inter-relationship between the Circadian Type Inventory and the Eveningness /Morningness scale as measured by the Composite Morningness Questionnaire. As the Languidness/Vigorousness score increased, there appeared to be a decrease in the Flexibility/Rigidity and Eveningness/ Morningness scores. That is, decreasing levels of ability to overcome drowsiness were associated with increasing rigidity in sleeping habits and a tendency to eveningness.

Indeed, there is some overlap between Rigidity and Vigorousness items in the CTI. For example, the Rigidity scale item (3.1b), "If you are feeling drowsy can you easily overcome it if you have something to do?", could be regarded as a Vigorousness item based on Folkard's (1979b) concept of Vigorousness as an ability to overcome drowsiness. Similarly, the Vigorousness scale item (3.1a), "Do you tend to need more sleep than other people?", could be interpreted as a Rigidity item (Smith 1993).

5.1

In addition, there is further ambiguity with regard to the Eveningness/ Morningness question (3.2e), "During the first half hour after having a wakened in the morning, how tired do you feel?", which has elements that relate to both Morningness and Vigorousness (Folkard 1979b). It is of course possible that such confounding factors are relatively unimportant when dealing with people on the normal "day-orientated" routine, but may be much more significant in individuals crossing multiple time zones because of the necessity for alterations in their sleep/wake pattern.

As indicated earlier, work by Iskra-Golec (1993) has shown that for current shift workers, the best predictors of attitude towards shift work are flexibility of sleeping habits and the ability to overcome drowsiness as measured by the CMQ and CTI together with other questionnaires. However, in day workers, without previous shift work experience, no such predictors have been found. The shift worker of course has many similarities with the transmeridian traveller and the results in this study bear out the findings of Iskra-Golec that, as with day workers, the questionnaires were not predictive for inexperienced travellers. However, contrary to Iskra-Golec's findings, this study suggests that they are not a sensitive predictor of the severity of travel fatigue in experienced travellers either.

Hence, although the ability to balance sleep, fatigue and wakefulness appears well suited to measurement with a self report questionnaire, there are difficulties encountered in identifying subtle differences in circadian rhythm characteristics as shown by the relatively small range in scores from the CTI (Smith 1993), and it must therefore be concluded that the self-report questionnaire does not appear to be a suitable tool for the sensitive and unambiguous measurement of circadian rhythm characteristics and must be of limited use in a predictive capacity.

Despite this, work by Suvanto (1993) on female flight attendants operating Helsinki - Los Angeles - Seattle - Helsinki has found that personality may indeed be used as a predictor of alertness rhythm adaptation following transmeridian flights. In particular, the characteristics of neuroticism following westward travel as measured by the Eysenck Personality Inventory (Eysenck 1976), and eveningness following eastward travel as measured by the Eveningness/Morningness questionnaire (Torsvall 1980) have been shown to be reliable in this respect. In addition, earlier work had also shown that neuroticism may in part explain the perceived desynchronosis experienced by Finnish cabin crew following long haul flights (Suvanto 1990). However, it is clear that, although neuroticism shows some correlation, it is not useful in a predictive capacity. Indeed, with shift workers it has been found to increase with increasing experience of shift work and is therefore effectively behaving as an outcome measure (Verhaegen 1986).

Despite its limitations, the Traveller Profile Questionnaire has enabled information to be gained on the extent and nature of travel fatigue with respect to direction of travel. The most extensive and significant area of correlation related to symptoms experienced following journeys in an Easterly or Westerly direction.

The perceived severity of travel fatigue appeared greater for journeys in an east/west direction than for those travelling north/south. In addition, there was a significant correlation between specific symptoms of travel fatigue such as sleep disturbance, appetite disturbance, tiredness and reduced mental alertness and transmeridian travel. However, although the results suggested that the effects were worse following eastward flights, there was no statistically significant difference between travel in a specific direction, east or west. This may in part be due to the fact that the questionnaire was administered some time after the subject's last trip and will have resulted in some blurring of their recollection regarding the extent of symptoms with respect to direction of travel. However, this effect was minimised by ensuring that no more than six months had elapsed since their last trip which is reflected in the fact that subjects responded quite conclusively that east/west travel is more likely to cause significant travel fatigue than north/south travel.

However, there was a correlation between three of the directions of travel, north, south and west indicating that the tendency to experience travel fatigue was common to all three. The natural endogenous biological rhythm operates within a time frame of 25-26 hours, not the 24 hour day in which we live (Shephard 1984). It is therefore possible that the phase delay required to accommodate the prolonged wakefulness following a westward flight has more similarities with the fatigue caused by the physical and psychological aspects of the flight itself than with the circadian disruption experienced following eastward travel thereby resulting in the observed correlation.

The Cronbach α coefficient of 0.816 for the items in Questions 2.5 and 2.6 indicated that these questions provided an internally consistent scale of fatigue. The suspect measures were Question 2.5 (E) and to a lesser extent Question 2.5 (W), inferring that these questions may not be measuring the same variable as Question 2.6. Indeed, on examining the questions in more detail, it is clear that Question 2.5 was asking for the perceived severity of travel fatigue with respect to direction of travel, whereas Question 2.6 was making an enquiry about specific symptoms following long haul flights irrespective of direction or resultant time change. Although both are important in assessing the overall effects of travel fatigue, the two questions are clearly asking about different elements and it is likely that the lack of direction specific information in Question 2.6 has therefore restricted the opportunities for analysis.

Further calculations using weighted responses to Questions 2.5 and 2.6 produced an overall "Fatigue" measure. The only correlation identified was with the Flexibility/Rigidity score of the CTI although this accounted for less than 5% of the variance. Previous work by Vidacek (1987) had identified Vigorousness as the scale correlating best with health problems in shift workers, although similarly it accounted for only about 6% of the variance. It may therefore be concluded that the measurement scales, although reliable, do not appear to be useful on their own in a predictive capacity.

5.2 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - DISCUSSION - COMPLIANCE

It is clear from Section 4.5 Phase 2 - Performance Measurement Study - Data Analysis that compliance was a significant factor in deciding the methods of data analysis in this study. All subjects were recruited by invitation and there was no shortage of potential applicants. The only limiting factor to enrolment was whether the subject felt they were likely to complete five long haul round-trips within the time scale specified. However, despite the ease of recruitment, compliance was such that it has only been possible to examine Psion data over a limited period for the outbound journey and, even with these restrictions, compliance across the day span Day -1 to Day 7 was only 64.4%.

As outlined in Section 4.3 Phase 2 - Performance Measurement Study - Study Subjects, only one potential subject declined to be included in the study and of the remainder, only one was withdrawn by the author as a result of poor compliance. All other subjects reported that they had satisfactorily completed the Psion tasks as required. Because of problems with data handling and the necessity for an extensive data preparation phase (see Section 4.4), it was not possible to review subject compliance at the end of each trip, and, therefore, the first time the opportunity arose to examine the data critically was following completion of the data collection and preparation phases.

The subjects recruited during the author's employment with AEA Technology (United Kingdom Atomic Energy Authority) all came from a research based environment and indeed the majority had themselves been research students having successfully completed PhD degrees in the fields of physics, chemistry or engineering. However, despite the self selection of subjects and their research experience, individual compliance, particularly during the latter part of their time overseas and following their return home was far from complete.

In an attempt to identify possible reasons for the failure of these subjects to comply with instructions given to them, perhaps the best parallel is to review studies of compliance in health care providers (Meichenbaum 1987), who, like the research scientists in this study, are themselves well aware of the implications of non-compliance.

It is well known that health care providers are no more likely to carry out health protective behaviours, such as stopping smoking, than are lay persons despite their greater knowledge (Salovey 1986) and, even at a practical level, health care providers often do not follow clinical procedures they know should be implemented (Clute 1963, Jungfer 1964, Peterson 1980). A study conducted by the American Society for Internal Medicine (Hare 1973) found little correlation between the established criteria of delivery of treatment and the physician's performance. At much the same time, Kayne (1973) examined the drug preparation and administration in elderly patients in three extended care facilities that provided skilled nursing care after discharge from an acute care hospital. They reported an error rate of 20%. The errors included missed doses, wrong drug or dose administered, wrong route of administration and incorrect dosing interval. The cumulative picture across health care providers is one of widespread non-adherence to advised health care practices.

Attempts to modify behaviour have, to date, been generally unrewarding. Workshops, conferences, newsletters and information papers have all failed to bring behaviours up to optimal levels (Williamson 1971). Residents in internal medicine in the United States who were provided with instructions relating to a set of clinical actions for each of 13 common preventative functions were found to actively adhere to the recommendations less than 10% of the time (Cohen 1985) although the use of explicit check lists did appear to alter physicians' performance associated with the diagnosis and treatment of abdominal pain (DeDombal 1974). The latter point is of particular relevance to this study where great care was taken to provide full instructions and summary sheets on the use of the Psion Organiser (Appendices V and VI) although despite this, there appears to have been little positive effect on compliance.

As indicated above, the author was not able to review the completeness of the data until the end of the data collection phase, but, even it had been possible, the benefit of highlighting poor compliance to subjects is far from clear. One of the earlier papers on the provision of performance information to doctors (Payne 1976) noted that it failed to cause a change in the delivery pattern of the physicians' care, and this was borne out subsequently by Tierney (1986) who showed that performance feedback to physicians regarding the prescription of recommended preventative diagnostic tests only resulted in rates of adherence in the region of 15 - 30% compared to levels of 10 - 15% in the absence of feedback.

With this background, it is perhaps reasonable to begin to examine the possible causes for non-compliance in this study:

i) It is possible that despite agreeing to participate the subject may subsequently have felt that the study did not have any particular relevance to their individual circumstances.

ii) The study protocol may have appeared too complicated although this possibility was anticipated and the timetable for use of the Psion Organiser made as simple and non-intrusive to the subjects' daily work schedule as possible. Indeed, the timetable was developed in liaison with the subjects themselves at the outset of the study (see Section 3.9).

iii) The demands of the study may have been underestimated and the subjects may not have had sufficient time available to complete the protocol requirements. It is possible that the author's expectations may have been unreasonable in view of the time commitment necessary to complete the tests and diaries which required the subjects to use the Psion Organiser for approximately 15 minutes each day.

iv) There was no payment for participation in the project and involvement was based entirely on the premise that the results of the study may assist the subjects to better deal with the effects of regular long haul travel in the future.

Previous studies using the Psion Organiser (Totterdell 1992) have found that subjects enjoyed using the computer and preferred it to pen and paper tests although compliance figures were comparable (Folkard 1990b). However, the Psion had the advantage that all data were automatically date and time stamped which was not possible with pen and paper tests unless an observer was present throughout. The overall compliance in a Psion study of site security workers (Totterdell 1992) was 50.2% for two hourly test sequences and over 75% for the daily sleep diary although compliance was markedly higher when the subjects were on shift compared to tests performed in their leisure time (68.6% compared to 56.3% in the first half of the study dropping to 54.8% and 30.4% respectively in the second half of the study). This had been anticipated and, as a result in this study, the author was more judicious with regard to the number of tests required during the course of data collection in the clear knowledge that the day span under consideration would extend across both work and rest days. However, despite this, adherence to the daily timetable was still far from complete even though the programme had been developed in liaison with the subjects themselves in an attempt to maximise compliance.

It is known that patient compliance is enhanced when the individual is given the attention of a health care provider (Meichenbaum 1987). In this study, subjects were seen personally by the author at the beginning and end of each trip to deliver and retrieve both the Psion Organiser and travel questionnaires and to enable a discussion to take place regarding the trip. Despite these efforts, compliance was still lower than might have been hoped, although it is some small reassurance that studies which have demonstrated benefit from the attention of health care providers (Nessman 1980) did so only after spending a prohibitive length of time with the individual.

The literature would appear to indicate that memory is one of the principle limiters to compliance in many individuals (Meichenabum 1987). In this study, prompts regarding the use of the Psion Organiser were included on the cover sheet of the travel questionnaires (see Appendix IVa) but it would appear that these alone were not sufficient. Behavioural feedback and performance indicators need to be built into any programme to ensure adherence but although subjects were provided with immediate feedback on their performance in the Choice Reaction Time and Memory Search Task tests, this appears to have been insufficient to improve compliance.

Finally, as with any protocol, there is the possibility of loss of motivation by the subject. A change in pattern of behaviour such as the need to comply with the Psion timetable is difficult for any individual to adhere to although it may be argued that the possibility of improved health or quality of life ought to be sufficient reason in itself.

It is clear that the principal advantage of the Psion Organiser in enabling time series data to be collected by subjects engaged in long haul travel has also been a major limiting factor as adherence to the project timetable relied entirely on the subject's conscientiousness. In addition, the author had no control or knowledge of the circumstances under which the TEST sequences were completed and it is likely that the ambient conditions of light and noise will have varied considerably and could have affected performance. In addition, interruptions during tests may also have occurred (Totterdell 1992), which will have additionally affected compliance.

5.3 PHASE 2 - PERFORMANCE MEASUREMENT STUDY DISCUSSION - GENERAL

The protocol for this study required that 20 subjects should each complete 5 long haul round-trips during the period of data collection. However due to circumstances outside the control of the author, only 88 trips were completed, of which 86 provided usable data.

A preliminary review of results for the cognitive performance Memory Search Task (Table 30), indicated a marked Trip effect with significantly better response times in Trips 2, 3, 4 and 5 compared with Trip 1 although more extensive analysis of the data provided the reason for this apparent improvement. Subjects were instructed to perform the Psion Test sequences for 7 days before departure on their first long haul trip to minimise any residual practice effect whilst overseas. Unfortunately, it is clear from the results that most subjects did not commence the tests until the day of departure, thereby invalidating much of the data obtained from Trip 1.

Early in the course of data analysis it was clear that subjects had completed the diary elements of the Psion programme (STARTDAY and ENDDAY) more conscientiously than the TEST sequences. As a result, the diaries frequently provided base-line pre-departure data for the subjective rating scales and therefore allowed more satisfactory comparisons to be made between pre-flight and post-flight results. However, as indicated above, the first TEST sequence available for analysis was often on the day of departure and, therefore, reluctantly it was necessary to use Day 0 as the base-line despite its obvious limitations. Nevertheless, although it is likely that the disruption imposed by the day of travel will have had an effect on the subjects' ratings of affect and well-being, the tests of cognitive performance are less likely to have been affected as the subject will not have suffered significant sleep loss, fatigue or circadian desynchronisation, the factors most likely to affect their performance (Cameron 1973, Hartman 1967), at the time of completion of the Serial Choice Reaction Time and Memory Search Task tests. Therefore, in the absence of pre-trip data, it would appear that it is acceptable to use the test results from Day 0 as a base-line for subsequent comparisons.

5.4 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - DISCUSSION - MOOD, AFFECT AND WELL-BEING

Transmeridian air travel affects the human circadian system in two ways:

i) by shifts in the habitual rest/activity cycle, and

ii) by shifts in the temporal characteristics of the environment.

These two effects both result in desynchronisation between the biological and environmental time systems (Wegmann 1981) and until the circadian system is completely realigned with the new zeitgebers, the traveller will be in a state of external desynchronisation where the internal circadian cycles no longer bear a fixed phase relationship to the time of the external cycles (Graeber 1982).

Theoretically, it is possible for the circadian system to be in a state of external desynchronisation where the various internal rhythms continue to maintain fixed temporal relationships amongst themselves while their periods adjust together towards the shifted zeitgeber schedule (Halberg 1977). However, the weight of evidence indicates that the endogenous rhythms adjust at different rates following transmeridian flights (Aschoff 1975) leading to internal desynchronisation. In addition, this tendency towards spontaneous internal desynchronisation increases with increasing age (Wever 1982) and, whilst not affecting sleep latency, age does significantly reduce sleep duration (Harma 1994a).

All of these factors may affect the business traveller who is often required to perform to a high level and to make important decisions following a long haul flight. It is known that the rates of resynchronisation of different

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psychological variables vary considerably with the commonest complaint associated with, and due to transmeridian desynchronisation, being fatigue (Hawkins 1978). Relatively few studies up to now have included a quantitative assessment of the elements of fatigue in addition to other more subjective measures and an attempt has been made to address the shortfall in this study.

There are 3 main sources of fatigue:

i) loss of sleep during the usual sleep span whilst aboard the aircraft

ii) wakefulness during the local day while the sleep/wake cycle is still externally desynchronised and at a point more appropriate for sleep, and

iii) loss of sleep during episodes of waking at night as a result of an unadjusted sleep/wake cycle (Graeber 1982)

Synchronisation of circadian rhythms in man occurs to a large degree as a result of social time cues (Aschoff 1978). However, because social as well as physical synchronisers are shifted simultaneously, transmeridian flights favour re-entrainment of biological rhythms in contrast to shift work where environmental and social synchronisers diverge (Wegmann 1981).

The assessment of fatigue, affect and well-being in this study was based on subjective rating scales for nine variables, Alertness, Cheerfulness, Calmness, Effectiveness, Mental Demand, Time Pressure, Disorientation, Appetite Disturbance and Physical Tiredness. As a result of the low level of compliance and poor understanding by subjects, it was not possible to examine the scales of Time Pressure or Disorientation, but the remaining seven scales were analysed extensively using the method of Repeated Measures Analysis of Variance.

Each table of results in Section 4.8 details the number of trips providing data for the measurement under scrutiny. The figure represents the total number of trips, either second, third, fourth or fifth contributing data for the Time Period and Day Numbers in question. The tables do not indicate the number of subjects contributing, but simply record the total number of trips available for analysis. Every effort was made to ensure that only analyses comprising at least 20% of the available 66 trips (> 13 trips) were undertaken. However, at times it was necessary to use Time Periods and day spans with fewer trips in order to make any comparisons, although, of course, it is more difficult to draw firm conclusions from small data sets.

Circadian desynchronisation may be thought of as a disturbance of the temporal order within the individual and an inevitable, albeit temporary consequence of transmeridian travel. It is likely that this will have an effect on the traveller, certainly with respect to well-being and possibly with respect to performance. Indeed, there is no doubt many symptoms of impaired well-being do occur in passengers during the transition from the pre-flight to the post-flight steady state (Wegmann 1981). However, some of these symptoms may be caused by factors other than the time zone shift such as the stress and excitement of air travel or the alien environment. It is for this reason that the term "travel fatigue" has been used for much of the time in this study rather than the more familiar "jet lag" as the latter is more commonly associated with the effects of time zone shifts rather than the overall effects of long haul flying. Nonetheless, some symptoms, such as appetite disturbance and fatigue, are undoubtedly related to internal desynchronisation and impair the individual's subjective well-being.

Many of the business trips examined in this study were of short duration and it is therefore probable that in many cases the circadian rhythms of subjects did not synchronise completely to local time during their stay overseas. This would have created an additional confounder had a separate examination been made of the outward and return journeys comparing synchronisation rates eastwards and westwards as part of the same trip. It is therefore perhaps somewhat fortuitous, although of course disappointing, that low compliance enabled only data from the outward journey to be examined. Nevertheless, it is still worthwhile to consider the question of re-synchronisation in a little more detail before critically reviewing the results obtained.

Harma (1993) examined the effect of 4 day round-trips over 10 time zones on the circadian variation in salivary melatonin and cortisol in airline flight attendants. It was found that following arrival in the United States, the maximal phase delay of the hormonal rhythms was only 5 to 6 hours, that is, only 50% - 60% of the total time shift of 10 hours. Within 4 days of the subjects' return to their native Finland, the phase delay of the salivary melatonin rhythm was on average 1 hour 37 minutes compared to the control before the flight. Thus, if the time spent abroad had been longer, a longer re-synchronisation time would have been required on return home. This finding has been confirmed by (Wegmann 1986) who, when looking at Boeing 747 air crews operating between Frankfurt and the US West coast, found that circadian re-synchronisation did not occur during the lay-over in the United States because of the relatively short time scale. Indeed, like Harma, he found that the circadian system had only shifted by about 5 hours before the return flight commenced. The required re-adaptation to home base time would therefore be comparable to conditions after a transition of only 5 time zones.

The mood ratings, Alertness, Cheerfulness, and Calmness were completed by the subjects on 4 separate occasions each day. Poor compliance limited the analysis to assessments performed in Time Period 1 and the overall daily rating in the ENDDAY diary. In addition, the day spans under consideration were limited to a maximum of 7 days following departure on the outward journey. However, within those 7 days, 3 different day spans were used for assessment:

i) Days 0, 1, 2 and 3
ii) Days 4, 5, 6 and 7
iii) Days 0, 1, 2, 3, 4, 5, 6 and 7

On examining the subjective rating of Alertness, there was no apparent Day effect across Days 0, 1, 2 and 3 or Days 4, 5, 6 and 7. However, when examining Days 0, 1, 2, 3, 4, 5, 6 and 7 there was an indication of a Day effect approaching statistical significance at the 5% level. Further analysis comparing each day separately with the base-line (Day 0), identified a clear Day effect for Day 5 (Probability < 5%). General inspection of the results indicated that the lowest level of Alertness occured on Day 3 although due to wide variability this did not reach statistical significance. However, the findings are based on only 6 trips and, therefore, little significance can be placed on them.

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Ratings of Alertness based on the subjects' assessment of the whole day were included in the ENDAY diary and provided much clearer results. There was a marked Day effect, most significant when using Day -1 as the base-line and examining the day span Days -1, 1, 2 and 3. This finding was statistically significant at the 1% level showing a decrease in Alertness on Day 1 compared to Day -1 which then slowly rose on subsequent days such that by Day 3 the difference was no longer significant. These results indicate a decrease in Alertness for the first two days after a long haul transmeridian flight and echoes the findings of Harma (1994b) whose work has shown that for flight attendants on 4 day round-trips over 10 time zones, alertness was at its lowest immediately following a transmeridian flight but returned to normal levels by the fifth day.

Although it is tempting to attribute decreased alertness to the temporary disruption induced by transmeridian travel, Moore Ede (1993) has defined nine switches of alertness, of which the biological clock and sleep are just two. His work has concentrated on individuals in jobs requiring vigilance and may therefore not be directly comparable with subjective rating scales of Alertness performed at rest in transmeridian travellers. However, it is nonetheless worthwhile to bear in mind that the subjective assessment of alertness is based on a number of factors, all of which have an influence and may include:

i) a perception of danger which will increase alertness

ii) exercise, which may stimulate alertness

iii) the biological clock with its bipolar rhythm of alertness

iv) sleep, which quite separate from our own innate circadian rhythm, is driven to some extent by the length of time since the individual's last sleep.

v) food, drink and drugs, all of which may affect alertness

vi) light, which provided it is of sufficient intensity will dramatically suppress sleepiness in workers on night shift

vii) temperature, as sultry heat induces sleepiness

viii) sound, as intermittent, irregular sounds increase alertness, and finally

ix) smell, which although still in the early days of investigation, may be a factor in increasing alertness.

Analysis of the results obtained for the scale of Cheerfulness demonstrated no clear Day effect although there was again an effect, bordering on statistical significance when examining Days 0, 1, 2, 3, 4, 5, 6 and 7 indicating an increase in Cheerfulness following arrival overseas. As before, a single day, Day 6 in this case, demonstrated statistical significance at the 5% level when compared with the base-line.

As before, examination of the results obtained from the ENDDAY diary demonstrated no overall Day effect although the subjective rating of Cheerfulness on Day 2 was higher than the base-line (Day -1) and the difference significant at the 5% level.

Finally, an examination of the results obtained for Calmness yielded a similar pattern. There was no apparent Day effect over Time Period 1, but the ratings performed as part of the ENDDAY diary did provide evidence of a

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Day effect, significant at the 5% level and demonstrating increased Calmness for the first 2 days overseas

In summary therefore, apart from rather questionable findings for the scales of Alertness and Cheerfulness, none of the ratings demonstrated a clear, statistically significant Day effect over Time Period 1. Compliance was such that it was not possible to examine any other Time Period and therefore no conclusion can be drawn regarding the presence or absence of a Time of Day effect.

With regard to assessments of well-being for the day as a whole and measured as part of the ENDDAY diary, all ratings showed a marked Day effect with Alertness being lower immediately after arrival overseas and then increasing on subsequent days such that by Day 3, the score was not significantly diferent from the base-line (Day -1). This compares favourable with the findings of Spencer (1991) who indicated there was a significant linear increase in the mean score for alertness on each recovery day throughout the recovery period following a polar flight between London and Tokyo.

In contrast, the scales for Cheerfulness and Calmness showed the opposite pattern, with scores being higher in the first 2 days following arrival overseas when compared to the base-line (Day -1) which begs the question as to whether all three scales are so intimately inter-related that decreased Alertness may in itself cause an increase in Cheerfulness and Calmness.

Further daily assessments of well-being were also made on retiring and the subjective ratings of Effectiveness, Mental Demand, Appetite Disturbance

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and Physical Tiredness all showed a statistically significant Day effect when examining Days -1, 1, 2 and 3 over 26 trips. Effectiveness decreased over Day 1 (Probability < 5%) and Day 2 (Probability < 1%) compared with the base-line (Day -1). A similar reduction in Day 1 (Probability < 1%) and Day 2 (Probability < 5%) was seen with Mental Demand. Conversely, with Appetite Disturbance there was a marked increase in Days 1, 2 and 3 (Probability all < 1%) when compared to the base-line (Day -1). The same pattern was seen for Physical Tiredness which again showed a statistically significant increases on Days 1, 2 and 3 (Probability all < 1%) compared with the base-line (Day -1).

For interpretation, it is most convenient to separate Effectiveness and Mental Demand from Appetite Disturbance and Physical Tiredness. Effectiveness showed a decrease in both Days 1 and 2, lower on Day 2, before returning towards base-line levels on Day 3. Mental Demand on the other hand demonstrated the lowest level on Day 1 before beginning to rise on successive days thereafter. It is likely that both scales are reflecting the same pattern of activity with low demand days on the first day or two after travel before commencing a more intensive work schedule later in the trip although it is of course possible that the self rating of Effectiveness may have been reduced early in the trip as a direct result of travel fatigue and decreased Alertness.

Further examination of the pattern of work and rest days over the day span under consideration indicated that the majority of subjects did indeed rest on Day 1 although the proportion failed to reach statistical significance (Probability > 10%) in comparison with the other days.

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Appetite Disturbance and Physical Tiredness both had significantly increased levels across the first 3 days overseas which probably reflects the effects of internal and external desynchronisation where the internal circadian periods are gradually realigning themselves with the zeitgeber cycle. As a result of this adjustment process, the traveller may have felt tired at inappropriate times of the day and may not necessarily have felt hungry at meal times. However, unfortunately, there were insufficient data to extend the analysis beyond Day 3 and therefore no information is available regarding the time required for complete resynchronisation.

As part of the ENDDAY diary, subjects were also required to record their alcohol consumption for the day in question. On reviewing the same day span across Trips 2-5 as previously, there was a statistically significant increase in alcohol consumption apparent from the first day after arrival overseas such that consumption increased from around one unit to a level in excess of three units per day. These results are very similar to those obtained by Harma (1994b) who, when looking at flight attendants travelling from Helsinki to Los Angeles found that alcohol consumption increased from an average of 0.8 glasses to 2-3 glasses per subject per day. This reflects the expectation that subjects are more likely to have socialised whilst overseas and possibly also used alcohol as a means of promoting sleep.

The use of alcohol as a sedative to initiate sleep is commonplace and, although it does induce sleep, it is an easily disrupted light sleep and returning to sleep after waking may be difficult. This poor quality sleep may result in performance decrements and may also impair the alignment process (Ferrer 1995).

5.4

The final variable to be considered was sleep. Data were collected as part of the STARTDAY diary completed on rising each morning, and enabled an analysis to be made of the Length of Sleep, number of Episodes of Waking and Quality of Sleep. Unfortunately, the persistent problem of compliance restricted the analysis and it was found that the only day span providing at least 20% of the available trips for examination was Days -1, 0, 1, 2 and 3. Day 0 was the Day Number assigned to the day of travel and was therefore not representative with respect to any parameters relating to sleep. This was particularly true for eastbound flights, all of which passed through a local night. As a result, two analyses were performed on each data set. The first using the full day span and the second using identical data, but with the values for Day 0 omitted.

The sleep length was calculated by SAS and converted into seconds from data entered in response to the questions outlined in Section 3.12. Statistical analysis failed to demonstrate a Day effect for either day span.

Interestingly, subjects had also indicated their preferred times of going to bed and rising together with their ideal length of sleep in the Traveller Profile Questionnaire employed in Phase 1 of the study. Comparison of ideal and actual Length of Sleep showed a marked difference between ideal sleep length based on times of retiring and rising compared with the subjects' estimate of their preferred length of sleep. The latter assessment is likely to be the more accurate representation of a subject's actual sleep requirements as most individuals would choose to retire earlier and rise later than they actually need to given no constraints. On this basis, there was no significant difference between the preferred and actual Length of Sleep taken by subjects whilst using the Psion Organiser before, during and after their overseas trip.

Additional analysis looked at the number of Episodes of Waking, which, although on general inspection appeared to show an increase on Days 1, 2 and 3 compared with the base-line (Day -1), failed to show a statistically significant difference (Probability > 10%). However, examining Day 3 alone and comparing this with the base-line, the increase in the number of Episodes of Waking did approach statistical significance (Probability < 10%).

The final variable to be considered was Quality of Sleep. This was assessed by subjects using a familiar 20-point bipolar rating scale. As before, results failed to indicate an overall Day effect but there was a significantly lower Quality of Sleep on Day 1 compared with the base-line (Day -1) (Probability < 5%).

Sleeping in a different place and at a different time is particularly disruptive to the individual's regular routine and is frequently reported as a problem by a long haul flight and cabin crew (Haugli 1994). The addition of other stressors such as a punishing overseas business schedule, is likely to exacerbate disturbed sleep patterns. Sleep disturbance is one of the major subjective complaints of transmeridian air travellers and difficulty in falling asleep, repeated waking during the night and shortening of the sleep period by early morning waking are all symptoms which have in the past been substantiated by sleep diaries (Klein 1976).

This study has examined three parameters with respect to sleep and the results appear to be similar to the findings of a number of studies examining the sleep patterns of long haul air crews. Dement (1986) studied crews before and after flying one of two routes, San Francisco to London or San Francisco to Tokyo and found no noticeable changes in sleep length or subjective assessment of sleep quality in either group. Subjects were found to be reasonably accurate in judging the amount of sleep and therefore this added further credence to the results.

Interestingly, it is clear that other studies have suffered from similar problems with compliance. A study by Harma (1994b) examining the effect of 4 day round-trip flights over 10 time zones on 40 flight attendants, found that the enquiry 'How did you sleep?' was answered by all respondents on only 10 days out of the 22 days of the study.

Work by Wegmann (1986) on Boeing 747 air crews operating between Frankfurt and US West Coast, showed that pilots did not suffer at all from sleep loss when compared with their normal sleep habits at home base, although of course this may in part be due to conscious efforts by the crews to ensure that they did get enough sleep. Once again, as with Dement's study (1986), Wegmann found that subjective estimates of sleep duration correlated well with objective measurements although it was clear that the number and length of wakings was frequently mis-judged. Previous work by Wegmann (1981) had indicated that the average sleep loss of air crews on long distance routes was about 2 hours per day although sleep loss appeared to be associated primarily with the number of night flights rather than the number of time zones crossed.

With regard to subjective ratings quality of sleep, Wegmann (1986) found that subjects slept less efficiently and rated their sleep subjectively worse on their first night overseas, a finding which was echoed in the present study. However, despite his conclusion that the short lay over on trips to the US West Coast prevented complete circadian resynchronisation and therefore reduced the time required for adaptation following return home, Stone (1993), examining the duty and rest periods of air crew operating the polar route from London via Anchorage to Japan, found that shorter schedules caused more disruption in the normal sleep pattern. It is possible that this may be due to the greater frequency of "first nights" encountered on short trips and therefore indicates that careful consideration needs to be paid to the length of overseas trips in order minimise the subjective disruption on both outward and return journeys.

It would appear therefore that the findings of this study with respect to sleep are broadly in line with previous workers and that whilst sleep disturbance, difficulty falling asleep, repeated wakings and shortening of the sleep period have all been reported in the past both anecdotally and in sleep diaries, none of the indices under consideration reach statistical significance in this study apart from reduced Quality of Sleep on the first day after arrival overseas. It is of course possible that the lack of significant findings in this study is because of a response bias and that compliant individuals completing the STARTDAY diary did so because they had had a good nights sleep and those subjects who suffered the effects of disturbed or poor sleep were so affected that they failed to comply with the protocol and therefore did not complete the diary entry on the Psion Organiser.

5.5 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - DISCUSSION - COGNITIVE PERFORMANCE

This part of the study required subjects to perform TEST sequences involving Serial Choice Reaction Time and Memory Search Task tests three times daily, before during and after their overseas trip. With the exception of Trip 1, the protocol required subjects to commence the tests on the day before travel and to continue for 7 days after arrival overseas before repeating the pattern on the return journey. As previously indicated, compliance was such that only results from Day -1 to Day 7 from the outbound journey were analysed. By restricting the day span, overall compliance was 64.4% which compares favourably with early Psion studies (Totterdell 1992), although fails to reach levels subsequently achieved by Totterdell in his studies on nurses (1995a, 1995b). However, performance is of course a function of the waking subject and the reduced compliance experienced in this study may therefore in part be due to the reduced levels of arousal in subjects at certain times of the day resultant on their presumed circadian de-synchronosis.

Analysis of the results from the Serial Choice Reaction Time test was undertaken using the same Repeated Measures Analysis of Variance as with the subjective rating scales of mood, affect and well-being. Data obtained from Trip 1 was omitted to minimise any residual practice effect and the Mean Choice Reaction Time for correct responses, Raw and Transformed data for Percentage Accuracy and Transformed Number of Gaps examined in some detail. The analysis was performed across different day spans and Time Periods for Trips 2-5. As discussed in Section 4.5, Days 0, 1, 2, and 3 were used as the standard span, although other ranges were also investigated. Unfortunately, although different Time Periods were examined, it was not possible to assess the presence of a Time of Day effect as subjects providing data late in the day (Time Period 3) were not necessarily the same individuals who had provided data for Time Period 1 thereby making any direct comparisons impossible.

Examining the Serial Choice Reaction Time test, there was no Day effect apparent for the Mean Choice Reaction Time for correct responses across Time Periods 1 and 2 for Days 0, 1, 2 and 3 or Time Period 1 for either Days 4, 5, 6 and 7 or the complete span, Days 0, 1, 2, 3, 4, 5, 6 and 7. Days 4, 5, 6 and 7 gave the largest number of trips of which to base the assessment (29 trips) but was likely to be assessing a period after which any performance decrement would have largely resolved. Indeed, for the planning of business trips, it is most important to know whether there is any affect on performance during the first day or two after travel although complete assessment requires knowledge not only of the daily performance level, but also of the total range of daily performance variation, that is, the circadian amplitude (Graeber 1982). The likely degradation in tasks assessing cognitive and psychomotor performance is small and has previously been found to reach statistical significance only on the first day after eastward travel (Klein 1980a). Unfortunately, adopting the repeated measures method of analysis limits the quantity of data available for analysis and does not allow separation of eastward and westward flights whilst retaining an acceptable number of trips for assessment. In addition, although frequent travellers present themselves as ideal subjects for this type of study, their extensive experience makes them a very select group and one from which it is difficult to generalise to other populations (Graeber 1982) and this may therefore additionally explain the lack of a Day effect.

5.5

The Percentage Accuracy in the Serial Choice Reaction Time Test was also examined, although, once again, no convincing overall Day Effect was apparent. However, there was some indication of an improvement in Accuracy by Day 3, following a dip on Day 2. This was more marked in Time Period 2 although based on only 6 trips and therefore of limited validity.

During the course of the Serial Choice Reaction Time test, failure to respond to the stimulus within one second resulted in the trial being recorded as a "Gap" and the percentage "Gaps" calculated by the Psion Organiser. The "Gaps" were considered to be rare events and therefore transformed to stabilise the variance before further analysis.

The Transformed Number of Gaps averaged from 2% to 3% and showed no Day effect apart from a statistically significant reduction in Time Period 1 on Day 7 compared with the base-line (Day 0) although this result was again based on only 6 trips (Probability < 5%).

In addition to the Serial Choice Reaction Time test, cognitive performance was further measured using a modified 7 letter Sternberg Memory Search Task (1969). The Mean Correct Response Time over 40 stimuli was calculated for both true positive and true negative results together with the Proportion of Correct Responses over the same series. The same Time Periods, Trip Numbers and trips were used as for the Serial Choice Reaction Time test. Once again, there was no demonstrable Day effect for either Mean Correct Response Time or Transformed Proportion of Correct Responses.

5.5

The use of the Psion Organiser has previously been validated by Totterdell (1994, 1995a, 1995b) and employed extensively, both as a self report vehicle and for tests of cognitive performance. Compliance in Totterdell's studies have averaged 82% to 85% for subjective mood ratings and 91% to 99% for sleep diaries extending over 14-30 days. The indications are therefore that the Psion, together with its diaries and tests are acceptable to subjects. However, it raises once again the question of compliance in this study and it is likely that the demanding schedule imposed on subjects before, during and after their overseas trip is one of the principal reasons for non-compliance. However, ther are other factors which need to be taken into account.

Performance tests by their very nature require concentrated effort over a short period of time and no matter how fatigued the subject may be, it is likely that they will nonetheless be able to manage intensive work for a short time. It is possible therefore that non-compliance in itself is an indirect measure of performance, and the fact that a subject fails to undertake a test or diary sequence may in part be due to poor motivation and time pressure as previously mentioned, but may also in part be due to reduced performance and a consequent failure to fulfil daily obligations.

When a subject arrives in a foreign country after crossing several time zones in the course of a transmeridian flight, all zeitgebers, both physical and social, are phase shifted simultaneously and by the same amount. Klein (1977) observed that the rhythms of different performance functions adjust at different rates to the imposed phase shifts and this was borne out by Monk (1978) who concluded that the memory load of a particular task influenced not only the phase of its circadian rhythm, but also the rate at which the rhythm adapted to a new schedule. Performance, like alertness, improves during the day, reaches a peak during the early evening and then declines overnight, with the lowest levels in the early morning (Pascoe 1994). Klein (1981) examined performance changes following flights crossing 6 time zones and on average, maximal impairment reached 8% for westbound and 10% for eastbound flights respectively when compared with pre-flight levels. The decrement was often demonstrable for up to 5 cycles but was not statistically significant after the third post-flight day.

While the purpose of the present study was clear, the analysis was significantly compromised by poor compliance. Some changes were demonstrated that were broadly consistent with expectations for the subjective ratings of well-being, but analysis of the tests of cognitive performance using the method of Repeated Measures Analysis of Variance failed to establish any effect following transmeridian flights. The method employed relies heavily on there being no missing data, and, therefore, in view of the level of compliance it is possible that a Day or Time of Day effect may have failed to manifest itself.

In order to answer this question and use significantly more of the available results over the day span Day -1 to Day 7, an alternative method of analysis was employed. It was necessary to remove the difference between subjects with respect to variability and mean values present as a result of the learning effect and to combine the data in such a way that they could be thought of as coming from a single subject. This was achieved by fitting a seventh degree polynomial to the available data for each individual and calculating the residual from the fitted curve. Following a Z-transformation, the data were then used in 2 and 3-way Analyses of Variance using the same five measures of cognitive performance with Day and Time as the main effects.

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A number of subjects failed to perform the final daily TEST sequence before their evening meal as requested and there was therefore the possibility that tests performed later in the day were degraded as a result of alcohol consumption during the evening. As a result, separate analyses with and without performance data obtained in Time Period 4 (after 20^{00}) were undertaken and showed that inclusion of the late evening TEST sequences had no effect on comparisons across Time Periods 1, 2 and 3 and little effect on the daily means.

Results for the Mean Choice Reaction Time in the Serial Choice Reaction Time test indicated that the base-line result (Day -1) was not always the fastest, and indeed there was no significant overall Day effect. However, there was a marked Time of Day effect where results obtained in Time Period 2 (10^{00} - 15^{59}) clearly were the fastest. In addition, there was a significant Day∗Time interaction indicating that the ranking sequence for the Time Periods differed from day to day. Nevertheless, graphical representation of the interaction (Figures 9, 10 and 11) confirmed that the results obtained in Time Periods 2 and 3 were consistently faster than those obtained at either end of the day (Time Periods 1 and 4) and that the pattern was generally sustained across the day span under scrutiny. In addition, the overall amplitude of the variability in the Time Scores was smaller between Day Numbers 1 and 6 than at the base-line.

Results for the Transformed Percentage Accuracy in the Serial Choice Reaction Time test again emphasised that the pre-trip base-line score (Day -1) was not significantly different from later values. As before, there was a marked Time of Day effect although, whilst the results in Time Period 2 were both fastest and more accurate, values obtained in Time Period 1 (before 10^{00}) were most accurate. As may be expected, results obtained in Time Period 4 (after 20^{00}) were both slowest and least accurate. The Transformed Number of Gaps in the Serial Choice Reaction Time test was effectively a measure of lapses in concentration but failed to show any Day or Time of Day effect.

Examination of the Memory Search Task indicated that only the Mean Correct Response Time showed any significant effect and, while there was no Day effect, there was a marked Time of Day effect and Day*Time interaction. Results obtained in Time Period 2 were once again fastest overall, but were slower than scores from Time Periods 3 and 4 (after 16^{00}) across the day span Day 3 to Day 6 (Figures 17 and 18). The pattern after Day 3 therefore represented an inversion of that seen at the pre-trip base-line (Day -1) which continued until Day 7.

Exploring this further and splitting the day span into 3 smaller sub-spans (Figure 19), it was confirmed that although the response time was fastest in Time Period 2 at the base-line and in the early part of the trip, this was not the case subsequently, and during the latter part of the overall day span, results from Time Periods 3 and 4 were clearly fastest. In addition, there was a reduction in the amplitude of the variability in the scores over Days 1 to 6.

This finding differed from the results obtained for the Mean Choice Reaction Time in the Serial Choice Reaction Time test where, despite some degree of cross-over, there was no sustained inversion. In that particular test, scores for Time Periods 1 and 4 were both generally slower than those for Time Periods 2 and 3 across the entire day span under consideration and this contrast clearly emphasises the difference in the two tests of cognitive performance.

It is likely that the finding of a Day∗Time interaction, and in particular the inversion of the Time Period ranking pattern, is providing evidence of the effects of desynchronisation in the performance rhythms under investigation and this is further supported by the fact that the rank order for the Mean Transformed Time Scores returned to the pre-trip pattern by Day 7 in both the Serial Choice Reaction Time test and Memory Search Task.

Across the overall day span Day -1 to Day 7, the variations from day to day were on the whole quite small for both performance tests and, apart from a few isolated points, fell within the limits set by the standard errors of the Mean Transformed Time Scores. In addition, the amplitude of variability for both tests was diminished following the transmeridian flight compared to the base-line.

Nevertheless, one variation in particular stands out as worthy of note. The results for both tests across the day span Day -1 to Day 7 obtained in Time Period 1, showed an uncharacteristic, but marked deterioration on Day 4 and it is suggested that this may be reflecting the cumulative effects of sleep disturbance following the subject's long haul flight and resulting time zone change.

The subjects were of course almost all following demanding business schedules and is important to bear in mind that the investigation of any test of human performance is beset by a number of problems that do not exist in corresponding investigations of other psychological processes. Probably the most obvious of these is that task performance is a voluntary activity, and, therefore, any alterations in performance may, to some extent, be merely a reflection of fluctuations in motivation, rather than an indication of true changes in efficiency (Colquhoun 1981). A second problem is fatigue arising from carrying out the task itself. It is difficult for even the most highly motivated subject to keep up performance for any length of time, and, as in this study, the usual solutions are to restrict the length of any test session and the total number of such sessions.

Whereas fatigue degrades performance at a task, repeated practice on the other hand enhances it. Practice effects occur even in the most apparently familiar kinds of activity when these are incorporated into a test situation. This may be overcome by having a sufficient number of tests before the start of the experimental series to ensure that the residual practice effects are minimised. However, this further adds to the difficulty of maintaining motivation over an extended observation period (Colquhoun 1981). This was clearly demonstrated in the present study where subjects failed to comply with the practice requirements and therefore necessitated the omission of data from Trip 1 during the Repeated Measures Analysis of Variance.

Following a long haul flight crossing multiple time zones, inherent circadian rhythms become displaced from their usual relation with the local environment and there subsequently arises a complex interaction between the effects on performance of long working hours and the cyclical variation in performance related to the time of day. Fatigue induced by work interacts with the normal circadian rhythm of performance (Colquhoun 1980) and the nature of this interaction is of particular interest in this study. Early work (Kleitman 1950) indicated that performance variations on some tasks tended to parallel those in body temperature, both over the normal day, and in their adjustment to shiftwork. However, the generality of this view has been questioned by more recent studies which have demonstrated both that the parallel of performance and temperature does not hold for all tasks and that the performance rhythms on different tasks may adjust at different rates to a phase shift. In particular, performance on tasks with a high "working memory" component exhibits a very different trend over the day to body temperature and adjusts more rapidly to night work (Folkard 1976, Folkard 1979c).

Subsequent work has supported the view that circadian performance rhythms differ markedly in their underlying control (Folkard 1990a, Folkard 1993) and rhythms with a relatively large exogenous component (accuracy in the Memory Search Task) are likely to show some immediate partial adjustment, while those with a larger endogenous component (reaction time and number of gaps in the Serial Choice Reaction Time test) may adjust more slowly. It is clear that in this study no Day effect was apparent for any of the parameters under scrutiny, but it must be borne in mind that the time taken to make a long haul transmeridian flight means that there is a period during the the flight when, very often, the subject rests and prepares himself mentally and physically for the zeitgebers of the new environment. Therefore the effects of a phase shift following time zone travel cannot be compared directly with the stepwise alteration in the sleep/wake cycles of the subjects in Folkard's study of shiftworkers (1993).

Returning again to the question of working memory, further work by Folkard (1976) has examined the effect of altering the short term memory load of a task. It was found that as the memory load increased, a different relationship with body temperature developed such that with high memory load, the relationship to temperature was opposite that assumed to exist by Kleitman (1950) with performance peaking in the early hours of the morning.

These findings are borne out in the present study where it is clear that the speed of response peaks earlier in the day with tests requiring higher memory load, namely the modified 7 letter Sternberg Memory Search Task, than with the Serial Choice Reaction Time test.

The difficulty in interpreting the results of performance tests following transmeridian travel is of course due to the effects of the resultant time zone change and likelihood of internal circadian desynchronisation. Nevertheless, a clear Time of Day effect has been demonstrated for the Mean Choice Reaction Time and Accuracy in the Serial Choice Reaction Time test as well as the Mean Correct Response Time for the Memory Search Task with all three measures peaking during the period 10^{00} to 15^{59}.

In addition, there were clear Day∗Time interactions for response times in both tests, more marked for the Memory Search task and demonstrating an inversion of the time pattern of peak performance during the trip.

Earlier work by Folkard (1976) indicated that the memory load of a particular task can influence the phase of its circadian rhythm and, in addition, may also affect the rate at which the phase of the rhythm adjusts to the new schedule (Monk 1978). Mental performance therefore does not appear to have a single rhythm with its own particular phase and rate of adaptation and this is confirmed in the present study where only some of the performance parameters exhibited a Time of Day effect. It would also explain why the Mean Correct Response Time in the Memory Search Task exhibited a phase inversion during the latter part of the day span under investigation, a phenomenon which was not apparent in the results for the Serial Choice Reaction Time test.

In studies of performance rhythms, it is of course important that the tests used should represent a meaningful simulation of certain aspects of the task which the worker will actually perform. Whilst the ideal is obviously to create job specific performance tests, this is clearly impractical in the present study. The tests chosen are both important in intellectual functioning and therefore considered appropriate in this respect. Indeed, the fact that the performance tests have demonstrated clear effects in the 2-way Analysis of Variance of transformed data confirms their validity as markers of cognitive performance.

The major limitation in using the Psion Organiser is that the investigator has no control or knowledge of the conditions under which the test is being completed. Ambient conditions such as light and noise are likely to have varied considerably and interruptions and social inhibitions regarding the use of the machine may also have been a factor. Hand and finger positioning and the eye-to-display distance are also likely to have changed and it must be the hope of authors using this method that these variations will not change or swamp the phenomena under investigation (Totterdell 1992).

In summary therefore, the tests of cognitive performance have demonstrated a clear Time of Day effect over the day span Day -1 to Day 7 for a number of the parameters under investigation indicating that speed, and to a lesser extent accuracy, peak between the hours of 10^{00} and 15^{59}. No overall Day effect was identified, suggesting that, for the particular performance tests employed in this study, there were no statistically significant differences between the days under scrutiny. However, there was a marked Day∗Time interaction with the effects of circadian desynchronisation persisting until the seventh day following the time zone shift.

These conclusions refer only to the performance tests employed, namely the Serial Choice Reaction Time test and Memory Search Task, and it is clear from the results and foregoing discussion that the degree of memory load in a given task does have significant effects on its circadian rhythmicity and subsequent readjustment following a phase shift.

SECTION 6

CONCLUSIONS

6.1 PHASE 1 - TRAVELLER PROFILE STUDY - CONCLUSIONS

This questionnaire-based study of 100 subjects, comprised 33 females with a mean age of 39.3 years (standard deviation 11.7 years) and 67 males with a mean age of 40.1 years (standard deviation 9.2 years), all of whom had completed at least one long haul trip crossing five times zones or more in the preceding six months. Although many subjects (44) made only one long haul trip per year and were relatively inexperienced, 52 individuals had completed more than 10 long haul trips previously and 16 averaged more than 5 each year.

In summary, the findings of the study were:

i) The perceived severity of travel fatigue appeared greater for journeys in an east/west direction than for those travelling north/south. However, although the results were suggestive, there was no statistically significant difference between travel in a specific direction, east or west.

ii) There was no difference in the perceived severity of travel fatigue between males and females with respect to direction of travel. However, independent of direction, males tended to record that their appetite and mental alertness was more affected than females.

iii) Experience of long haul travel made no difference to the perceived severity of travel fatigue for journeys in an easterly or westerly direction. However, for north/south travel, experienced travellers appeared

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to suffer less than inexperienced.

iv) Many subjects adopted their own practices for reducing the effect of travel fatigue. The most commonly used manoeuvres were to change to the destination time zone on boarding the aircraft and to adopt a normal night time sleep pattern immediately on arrival in the destination.

v) There was no difference in the personality scores between males and females as measured by the Circadian Type Inventory (CTI) (Folkard 1987) and the Composite Morningness Questionnaire (CMQ) (Smith 1989)

vi) Older subjects reported a greater ability to overcome drowsiness, although exhibiting more characteristics of morning types. However, little more than 8% of the variance in Languidness/Vigorousness (CTI) or Eveningness/Morningness (CMQ) scores was accounted for by age.

vii) Based on a smaller sub-population, alcohol consumption appeared to reduce the perceived severity of travel fatigue for journeys in a southerly direction.

viii) There was a significant correlation between symptoms of travel fatigue such as sleep disturbance, appetite disturbance, tiredness and reduced mental alertness and journeys in an easterly or westerly direction although again no discernible difference between travel in a specific direction.

ix) The questions employed in the Traveller Profile Study provided an internally consistent measure of fatigue as confirmed by a Cronbach α score of 0.816.

x) There was some inter-relationship between scores from the Circadian Type Inventory and the Eveningness/ Morningness scales as measured by the Composite Morningness Questionnaire, possibly due to a degree of overlap in items contained in the two questionnaires.

xi) There was no evidence to indicate that the Circadian Type Inventory and Composite Morningness Questionnaires significantly assisted in identifying those individuals who suffered most from the effects of travel fatigue. The only exception was a negative correlation between the Flexibility/Rigidity (F/R) score (CTI) and reduced mental alertness, although insufficient to be used in a predictive capacity.

xii) It was nonetheless possible to develop an equation of the form:

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"Fatigue" = 12.07 - 0.1 F/R Score

This measure of "Fatigue" accounted for less than 5% of the variance and confirmed the conclusion above that the Circadian Type Inventory and Composite Morningness Questionnaire, although reliable, could not be used alone in any predictive capacity to identify those individuals who would suffer most from the effects of travel fatigue.

6.2 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - MOOD, AFFECT AND WELL-BEING - CONCLUSIONS

This computer-based study of 20 subjects comprised 2 females and 18 males all of whom were required to undertake 5 long haul round-trips, each crossing 5 time zones or more during the course of data collection from March 1993 to February 1995.

The trips were of variable length from 2 to 25 days (mean 9.8 days, standard deviation 6.2 days) and by the end of data collection 88 trips had been completed of which 86 provided usable data. They comprised 49 eastward and 37 westward outbound journeys principally to the United States (-5 to -8 time zones) and Japan (+9 time zones).

During the course of the study, subjects used a pre-programmed Psion Organiser to collect data on mood, affect and well-being, both before and after their transmeridian flight, and an examination made of nine variables, Alertness, Cheerfulness, Calmness, Effectiveness, Mental Demand, Time Pressure, Disorientation, Appetite Disturbance and Physical Tiredness. Subjects were required to provide ratings for the first three scales at intervals during the day as part of the tests of cognitive performance (TEST) and, in addition, seven of the subjective scales were assessed for the day as a whole as part of the ENDDAY diary completed just before retiring.

In summary, the findings of the study were:

i) Compliance in Phase 2 of the study was disappointing and resulted in data analysis being restricted to the outbound journey only across the day span Day -1 to Day 7 where Day 0 was designated as the day of travel. However, by

6.2

imposing these limitations compliance was optimised and reached a level of 64.4%.

ii) A Repeated Measures Analysis of Variance was performed to take account of the possible correlation between measures for the same individual.

iii) It was clear that for the tests of cognitive performance, a practice effect was present in Trip 1, and, as a result, data from this trip was excluded from the analysis of all subjective rating scales of affect and well-being.

iv) The level of compliance dictated that analyses of the daytime mood ratings of Alertness, Cheerfulness and Calmness be limited to Time Period 1 (before 10^{00}). None of the rating scales demonstrated a clear, statistically significant Day effect across the day spans under consideration (between Day 0 and Day 7). Poor compliance precluded any assessment of Time of Day effect being undertaken.

v) With regard to subjective ratings for the day as a whole, there was a marked Day effect across the day span, Days -1, 0, 1, 2 and 3, for all scales: **Alertness** - was lower immediately after arrival overseas and then increased on subsequent days such that by Day 3 it was not significantly different from the base-line (Day -1).

6.2

Cheerfulness - was higher in the first 2 days overseas compared to the base-line (Day -1).

Calmness - was likewise higher in the first 2 days overseas compared to the base-line (Day -1).

Effectiveness - was lower in the first 2 days overseas compared to the base-line (Day -1).

Mental Demand - was likewise lower in the first 2 days overseas compared to the base-line (Day -1).

Appetite Disturbance - was significantly higher in Days 1, 2 and 3 when compared to the base-line (Day -1).

Physical Tiredness - was likewise significantly higher in Days 1, 2 and 3 when compared to the base-line (Day -1).

Analyses of the scales of **Time Pressure** and **Disorientation** were not performed due to poor compliance.

vi) Inspection of the data appeared to indicate that most subjects rested on Day 1 which would account for the lower ratings of Effectiveness and Mental Demand. However, the proportion working was not significantly different from the other days under study.

vii) Alcohol consumption showed a statistically significant increase, apparent from the first day overseas, from around 1 unit to a level in excess of 3 units per day.

6.2

viii) Data on the subjects' sleep pattern were provided in the STARTDAY diary and included information on Length of Sleep, number of Episodes of Waking and Quality of Sleep. Analysis was based on day spans across the range Day -1 to Day 3:

Length of Sleep - there was no statistically significant Day effect for the day spans under consideration.

Episodes of Waking - inspection of the data appeared to indicate an increase on Days 1, 2 and 3 compared with the base-line (Day -1) but the difference failed to reach statistical significance.

Quality of Sleep - showed no overall Day effect but there was a significantly lower Quality of Sleep on Day 1 compared with the base-line (Day -1).

6.3 PHASE 2 - PERFORMANCE MEASUREMENT STUDY - COGNITIVE PERFORMANCE - CONCLUSIONS

In addition to the subjective ratings of mood, affect and well-being, subjects also completed tests of cognitive performance using the Psion Organiser before and after their transmeridian flight. The tests were performed three times each day, on rising, at lunch time and before the evening meal although, as with the subjective rating scales, compliance levels dictated that data analysis be restricted to the outbound journey only across the day span Day -1 to Day 7 where Day 0 was designated as the day of travel.

Two separate performance tests were undertaken, a Serial Choice Reaction Time test consisting of two blocks of 80 stimuli and a modified 7 letter Sternberg Memory Search Task (1969) consisting of 40 stimuli. Results from the Serial Choice Reaction Time test were analysed for Day, Time of Day and Trip effects based on the Mean Choice Reaction Time for correct responses, Percentage Accuracy and Number of Gaps. Results from the Memory Search Task were likewise analysed using the Mean Correct Response Time for true positive and true negative results together with the Proportion of Correct Responses.

In summary, the findings of the study were:

i) As with the ratings of mood, affect and well-being, a Repeated Measures Analysis of Variance was performed to take account of the possible correlation between measures for the same individual. Data from Trip 1 were omitted because of the practice effect and in view of the level of compliance, no attempt was made to assess Time of Day effects.

6.3

i) a) **Serial Choice Reaction Time** - there was no statistically significant Day effect apparent for either the Mean Choice Reaction Time, Percentage Accuracy or Number of Gaps.

i) b) **Memory Search Task** - likewise, there was no statistically significant Day effect for either Mean Correct Response Time or Proportion of Correct Responses.

ii) In view of limitations in the Repeated Measures Analysis of Variance an alternative method of removing the practice effect from the data was employed and a further 2-way Analysis of Variance performed following polynomial de-trending and Z-score transformation using Day and Time as the main effects.

ii) a) **Serial Choice Reaction Time** - whilst the base-line (Day -1) Mean Choice Reaction Time was not always the fastest, there was no statistically significant Day effect. However, there was a marked Time of Day effect and Day∗Time interaction. Together with the score for the Percentage Accuracy, it was clear that overall the results in Time Period 2 (10^{00} - 15^{59}) were fastest and were also more accurate than those in Time Periods 3 and 4 (after 16^{00}), whilst those obtained in Time Period 1 (before 10^{00}) although slower, were most accurate. Despite the presence of a Day∗Time interaction, the effect was small and although the general time pattern for the Mean Choice Reaction Time was maintained across the day span Day -1 to Day 7, the Time Period ranking for each day varied and did not return to the pre-trip sequence until Day 7. The Number of Gaps failed to show any Day or Time of Day effect or Day∗Time interaction.

ii) b) **Memory Search Task** - only the Mean Correct Response Time demonstrated any statistically significant changes. There was no Day effect, but as before there was a clear Time of Day effect with the overall results obtained in Time Period 2 (10^{00} - 15^{59}) being the fastest. In addition, there was a highly significant Day∗Time interaction with inversion of the paired ranking of results obtained in Time Periods 1 and 2 (before 15^{59}) with those obtained in Time Periods 3 and 4 (after 16^{00}) across the day span Day 3 to Day 6.

iii) Overall, the tests of cognitive performance failed to demonstrate the presence of any significant Day effect on the days following long haul transmeridian flights. However, the method was able to identify a clear overall Time of Day effect with both speed of performance, and also in some cases accuracy, peaking in the middle portion of the waking hours (10^{00} - 15^{59}). In addition, speed of performance in the Memory Search Task peaked earlier in the day than that for the Serial Choice Reaction Time as may be expected for tasks of high memory load.

6.3

iv) Examination of the overall Day∗Time interaction for both performance tests showed that the pre-trip ranking pattern for speed of performance was not restored until Day 7 in either case. In addition, results for the Mean Correct Response Time in the Memory Search Task showed an inversion of their Time Period ranking between Days 3 and 6. Finally, the daily amplitude of variability in reaction time across the 4 Time Periods diminished in both tests following the time zone shift.

v) It is suggested that these findings confirm work by Folkard (1976) and Monk (1978) that cognitive performance is not governed by a single circadian rhythm and it would appear that overall, following a time zone shift of 5 hours or more, the average time required for resynchronisation of the performance rhythms under investigation in this study was 7 days.

vi) Although it was clear that many subjects rested on their first day overseas, the proportion was not significantly different to other days.

vii) The results obtained for the tests of cognitive performance alone do not indicate the need for any specific advice regarding the planning of business schedules in the first few days after a transmeridian flight. However, it is nevertheless important that travellers should appreciate that for the tests investigated in this study, it will take up to

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7 days before their performance rhythms return to their pre-trip patterns. There were, nevertheless, clear mood changes including reduced levels of Alertness and Effectiveness associated with increased Physical Tiredness in the first two days after a transmeridian flight and it would therefore seem prudent, in the light of both the mood and performance findings, to suggest to business travellers that they avoid important meetings and negotiations during this time.

6.4 CONCLUSIONS

This study was principally set up to investigate two questions. Firstly, whether personality profiles as measured by the Circadian Type Inventory (Folkard 1987) and the Composite Morningness Questionnaire (Smith 1989) are good indicators of susceptibility to the effects of travel fatigue and, secondly, whether the use of computer based diaries of mood, affect and well-being together with tests of cognitive performance using the Serial Choice Reaction Time test and Memory Search Task can identify any performance decrements attributable to travel fatigue on long haul business trips.

In answer to the first question, the Traveller Profile Questionnaire was developed and provided an internally consistant measure of fatigue. The questionnaire confirmed that transmeridian travel causes greater symptoms of travel fatigue than north/south journeys. However, although the results were suggestive, there was no statistically significant difference between travel in a specific direction, east or west. In addition, while there was some negative correlation between the Flexibility/Rigidity score as measured by the Circadian Type Inventory and their perceived symptoms, it was insufficient to be used in a predictive capacity to identify those individuals who would suffer most from the effects of travel fatigue.

With regard to the second question, two separate analyses of data obtained from the tests of cognitive performance failed to identify any significant overall performance decrement following long haul transmeridian travel. However, there was a clear Time of Day effect with both speed of performance and also in some cases accuracy being seen to peak during the middle portion of the waking hours (10^{00} - 15^{59}). The presence of a Day∗Time interaction demonstrated an inversion of the pre-trip Time Period ranking pattern for the Mean Correct Response Time in the Memory Search Task from Days 3 to 6 and, coupled with the findings from the Serial Choice Reaction Time test, indicated that it took approximately 7 days before the performance rhythms under investigation in this study reverted to their pre-trip pattern following a time zone shift of 5 hours or more.

In addition, there were significant changes in the subjective ratings of mood, affect and well-being. In particular, Alertness and Effectiveness were rated by subjects as being lower in the first two days after a transmeridian flight associated with increased Physical Tiredness.

As a result, in the light of the changes in mood ratings and the clear disruption of circadian performance rhythms despite the absence of any definite overall deterioration in performance, it would seem prudent to suggest to business travellers that they avoid important meetings and negotiations during the first two days after a transmeridian flight.

SECTION 7

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7 REFERENCES

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APPENDICES

APPENDIX 1

STUDY PROTOCOL

PROJECT PROTOCOL

DEGREE OF DOCTOR OF MEDICINE

THE EFFECT OF TRAVEL FATIGUE ON HUMAN PERFORMANCE

D J C FLOWER

The physiological effects of transmeridian air travel are well documented. However, as companies expand into new markets overseas, we are seeing an ever increasing number of business trips which involve both long distances and punishing schedules. This project will be looking at the effects of business and leisure travel, crossing five time zones or more in both an easterly and westerly direction and investigating the individuals perception of the severity of their travel fatigue and the effects on their intellectual performance as measured by standard psychological tests. No attempt will be made to control the eating, drinking or sleeping patterns of the subjects during their trip.

The study will be in two parts. In the first instance, questionnaires will be analysed from 100 experienced long haul travellers all of whom will have made a qualifying trip of five time zones or more in the preceding six months. They will be recruited through British Airways Health Services or from the Occupational Health Department of the United Kingdom Atomic Energy Authority either by direct approach or by responding to an advertisement in the site newspaper at Culham and Harwell Laboratories. The questionnaires will endeavour to evaluate the passengers subjective feelings of travel fatigue on long haul flights and to correlate these with standard psychological scales of vigorousness, flexibility and morningness in human circadian rhythms. The aim of this part of the study is to identify if psychological profiles are a good indicator of susceptibility to the effects of travel fatigue.

MD PROTOCOL - CONTINUED

The second phase of the study will examine performance following a long haul flight. Twenty regular travellers will be recruited by direct approach from both inside and outside the United Kingdom Atomic Energy Authority and British Airways. They will be invited to document details of their travel arrangements for each of five long haul trips and will be asked to keep a diary of their sleep pattern and alcohol consumption on a pre-programmed Psion hand held computer. In addition, they will be asked to perform choice reaction time tests and memory search tasks at intervals before, during and after each journey in an attempt to quantify the performance decrement which may be attributed to travel fatigue on long haul business trips.

APPENDIX II

PHASE 1 - TRAVELLER PROFILE STUDY

QUESTIONNAIRE

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

As part of the health surveillance programme undertaken by British Airways Health Services, we are looking at the way in which travel fatigue affects individuals during business trips overseas.

would be most grateful if you could spare a few minutes to complete the attached questionnaire and return it to me at the address below. This may be done anonymously if you wish, but we are also looking for volunteers to help us in subsequent stages of the project. If you would be willing to help, please do not forget to fill in section 6 at the end of the document.

Dr D J C Flower
Occupational Physician
British Airways Health Services
Speedbird House (S279)
Heathrow Airport
Hounslow
Middlesex TW6 2JA

Telephone: 0181 562 5674

1 GENERAL INFORMATION

Please answer the following questions as accurately as possible. Please note that the information you give will be treated in the strictest confidence.

1.1 Today's date ....

1.2 Age ....

1.3 Sex **(circle one)** Female Male

2 TRAVEL INFORMATION

2.1 Is this your first long haul flight (ie a journey of greater than 6 hours flying time)

(circle one) Yes No

If Yes go directly to section 3.

2.2 How many long haul round trips have you made in the past (both the outward and return sectors together count as one trip)

(circle one) 1 - 4 5 - 9 More than 10

2.3 On average how many long haul round trips have you made each year over the last five years

(circle one) 1 2 3 4 5 or more

2.4 To what extent do you enjoy having to make long haul trips **(circle one)**

Actively <u>dislike</u>				Actively <u>enjoy</u>
1	2	3	4	5

TRAVEL INFORMATION CONTINUED

2.5 How would you rate your perception of the severity of travel fatigue on a scale of 1 - 5 **(circle one)**

	No effects of travel fatigue				Severe effects of travel fatigue
Eastward flight	1	2	3	4	5
Westward flight	1	2	3	4	5
Northerly flight	1	2	3	4	5
Southerly flight	1	2	3	4	5

2.6 How frequently do you suffer from the following symptoms after a long haul flight? **(circle the appropriate number)**

		Almost Never	Quite Seldom	Some-times	Quite Often	Almost Always
a)	Sleep disturbance	1	2	3	4	5
b)	Appetite disturbance	1	2	3	4	5
c)	Physical tiredness	1	2	3	4	5
d)	Reduced mental alertness	1	2	3	4	5
e)	Other, please specify	1	2	3	4	5

2.7 Do you take any medication to combat travel fatigue? **(circle one)**

No trips		Sometimes		All trips
1	2	3	4	5

If you **do** take medication, what is its name?

....

Which directions of travel do you use the medication?
(Circle all appropriate directions)

East **West** **North** **South**

If you **do not** take medication, do you actively engage in any strategies to reduce the effects of travel fatigue? If so what do you do?

a) During flight ....

b) After flight ....

TRAVEL INFORMATION CONTINUED

2.8 Do you smoke? **(circle one)** Yes No

If Yes, how much do you smoke

Cigarettes/day ....

Cigars/day ....

oz tobacco/week ....

2.9 On board the aircraft what do you drink? **(circle all items that are appropriate)**

Tea/Coffee/Cola	Yes	No
Fruit Juice/Soft Drinks/Mineral Water	Yes	No
Alcohol - Wine/Beer/Spirits	Yes	No

3 PERSONALITY TYPE

3.1 The following questions are concerned with your daily habits and preferences. Please indicate what you prefer to do, or can do, and not what you may be forced to do by your present work schedule or routine.

Please work through the questions as quickly as possible. It is your immediate reaction to the questions that we are interested in, rather than a carefully deliberated answer. There are no "right" or "wrong" answers to any of the questions. For each question we simply want you to indicate which of the five alternatives best describes you, or your preferences, by circling the appropriate number.

		Almost Never	Seldom	Some-times	Usually	Almost Always
a)	Do you tend to need more sleep than other people?	1	2	3	4	5
b)	If you are feeling drowsy can you easily overcome it if you have something to do?	1	2	3	4	5

PERSONALITY TYPE CONTINUED

		Almost Never	Seldom	Some-times	Usually	Almost Always
c)	Can you miss out a night's sleep without too much difficulty?	1	2	3	4	5
d)	Do you find it difficult to "wake-up" properly if you are awoken at an unusual time?	1	2	3	4	5
e)	If you had to do a certain job in the middle of the night do you think you could do it almost as easily as at a more normal time of day?	1	2	3	4	5
f)	Do you find it easy to "sleep in" in the morning if you got to bed very late the previous night?	1	2	3	4	5
g)	If you go to bed very late do you need to sleep in the following morning?	1	2	3	4	5
h)	Can you easily keep alert in boring situations?	1	2	3	4	5
i)	Do you enjoy working at unusual times of day or night?	1	2	3	4	5
j)	Do you feel sleepy for a while after waking in the morning?	1	2	3	4	5

PERSONALITY TYPE CONTINUED

		Almost Never	Seldom	Some-times	Usually	Almost Always
k)	Do you get up later than normal when you are on holiday?	1	2	3	4	5
l)	If you have a lot to do can you stay up late to finish it off without feeling too tired?	1	2	3	4	5
m)	Does the time of day have a large effect on your mood and abilities?	1	2	3	4	5
n)	Do you find it as easy to work late at night as earlier in the day?	1	2	3	4	5
o)	If you have to get up very early one morning do you tend to feel tired all day?	1	2	3	4	5
p)	Would you be just as happy to do something in the middle of the night as during the day?	1	2	3	4	5
q)	Do you rely on an alarm clock, or someone else, to wake you up in the morning?	1	2	3	4	5
r)	Are there particular times of the day when you would avoid doing certain jobs if you could?	1	2	3	4	5

PERSONALITY TYPE CONTINUED

3.2 Please **tick** the response for **each** item that best describes you. Do not cross check your answers.

a) Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

05.00 - 06.30 am	....
06.30 - 07.45 am	....
07.45 - 09.45 am	....
09.45 - 11.00 am	....
11.00 am - 12.00 (noon)	....

b) Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening?

08.00 - 09.00 pm	....
09.00 - 10.15 pm	....
10.15 pm - 12.30 am	....
12.30 - 01.45 am	....
01.45 - 3.00 am	....

c) Assuming normal circumstance, how easy do you find getting up in the morning?

Not at all easy	....
Slightly easy	....
Fairly easy	....
Very easy	....

d) How alert do you feel during the first half hour after having awakened in the morning?

Not at all alert	....
Slightly alert	....
Fairly alert	....
Very alert	....

PERSONALITY TYPE CONTINUED

e) During the first half hour after having awakened in the morning, how tired do you feel?

Very tired	....
Fairly tired	....
Fairly refreshed	....
Very refreshed	....

f) You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is 7.00 - 8.00 am. Bearing in mind nothing else but your own "feeling best" rhythm, how do you think you would perform?

Would be in good form	....
Would be in reasonable form	....
Would find it difficult	....
Would find it very difficult	....

g) At what time in the evening do you feel tired and, as a result, in need of sleep?

08.00 - 09.00 pm	....
09.00 - 10.15 pm	....
10.15 pm - 12.30 am	....
12.30 - 01.45 am	....
01.45 - 03.00 am	....

h) You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day, and considering only your own "feeling best" rhythm, which **ONE** of the four testing times would you choose?

08.00 - 10.00 am	....
11.00 am - 1.00 pm	....
03.00 - 05.00 pm	....
07.00 - 09.00 pm	....

PERSONALITY TYPE CONTINUED

i) One hears about "morning" and "evening" types of people. Which **ONE** of these types do you consider yourself to be?

Definitely a morning type	....
More a morning than an evening type	....
More an evening than a morning type	....
Definitely an evening type	....

j) When would you prefer to rise (provided you have a full day's work - 8 hours) if you were totally free to arrange your time?

Before 06.30 am	....
06.30 am - 07.30 am	....
07.30 - 08.30 am	....
08.30 am or later	....

k) If you always had to rise at 06.00 am, what do you think it would be like?

Very difficult and unpleasant	....
Rather difficult and unpleasant	....
A little unpleasant but no great problem	....
Easy and not unpleasant	....

l) How long a time does it usually take before you "recover your senses" in the morning after rising from a night's sleep?

0-10 minutes	....
11-20 minutes	....
21-40 minutes	....
More than 40 minutes	....

PERSONALITY TYPE CONTINUED

m) Please indicate to what extent you are a morning or evening **active** individual?

Pronounced morning active (morning alert and evening tired)	....
To some extent, morning active	....
To some extent, evening active	....
Pronounced evening active (morning tired and evening alert)	....

4 SLEEP PATTERN

4.1 How much sleep do you feel you need each day? .... hours

4.2 Do you nap during the day **(circle one)** YES NO

If yes, how often and for how long ....

4.3 Given no constraints, what would be your preferred times of

a) going to bed? ....

b) getting up? ....

5 COMMENTS

Do you have any additional comments on your experiences or on this questionnaire?

6 FOLLOW UP STUDY

As mentioned in the introduction, a follow up study is planned that involves carrying a pocket computer with you for the duration of subsequent business trips and from time to time asking you to perform a few simple tests and measurements.

Would you be willing to participate in such a study? **(circle one)**

Yes No

A summary of the findings of this study will be available to participants at the completion of the project.

If you have circled Yes, please fill in your name, address and telephone number so that we may contact you. Again we would like to stress that all the information you give will be treated in the strictest confidence.

Name ....

Address ....

....

....

Telephone ....

Thank you for your help in completing this questionnaire.

APPENDIX III

PHASE 1 - TRAVELLER PROFILE STUDY

ADVERTISEMENT FOR VOLUNTEERS

APPENDIX III PHASE 1 - TRAVELLER PROFILE STUDY

ADVERTISEMENT FOR VOLUNTEERS

JET LAG AND TRAVEL FATIGUE

The Culham/Harwell Occupational Health Department are currently undertaking a questionnaire based study looking at the effects of jet lag and travel fatigue following long haul air travel. If you have made any long haul flight in the last six months and would like to consider taking part in the study, then please contact Dr David Flower on extension 3397 for further information.

This advertisement appeared in Volume 4, Issue 009, September 1993 of 'CH News', the information newsheet for employees of the United Kingdom Atomic Energy Authority on Culham and Harwell sites in Oxfordshire.

APPENDIX IVa

PHASE 2 - PERFORMANCE MEASUREMENT STUDY

OUTWARD JOURNEY QUESTIONNAIRE

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

OUTWARD JOURNEY

Thank you for agreeing to participate in the above study. As you are aware, much of the accumulated data will be on the hand held Psion computer, but in addition, we would like you to complete the attached questionnaire in order that we may assess other factors which may contribute to the overall effect of travel fatigue.

REMINDER - Could you please do the PSION diary and test sequences on the following days:

> On the day before departure and for 7 days after your arrival overseas,
>
> then
>
> On the day before your return home and for 7 days after your arrival back in the UK.

Thank you for your continued help.

David Flower
Occupational Physician

Telephone: 0181 562 5674

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

OUTWARD JOURNEY

Name .... Date of Birth ....

Department .... Extension ....

1 TRAVEL DETAILS

Date of travel ....

Final destination................................ Is this your first visit? Yes No

Via ....

(Please highlight cities where change of aircraft required)

Scheduled Departure time	....	Scheduled arrival time at final destination (local)	....
Actual Departure Time	....	Actual arrival time at final destination (local)	....
Class of Travel (First/Business/Economy)	....	Smoking/ Non smoking seat	....

Before today, when and to where was your last overseas trip?

....

1.1 CHECK IN ARRANGEMENTS

a) Before leaving for the airport had you been **(delete as appropriate)**

At work / at home

b) How would you best describe your arrangements for getting to the airport and checking in for your flight? **(circle one)**

Relaxed/ No Problems				Crowded/ Long Queues/ Other Problems
1	2	3	4	5

1.2 FLIGHT DETAILS

a) Drinks consumed before and during flight

Tea/Coffee/Cola	......	cups/glasses
Fruit Juice/Soft Drinks/Mineral Water	......	glasses
Alcohol - Wine/Beer/Spirits	......	units

(1 unit = 1 glass of wine **OR** 1 half pint of beer **OR** 1/2 miniature of spirits)

b) Did you try to sleep on board? **(circle one)** Yes No

If no, go directly to question 1.3

If yes, please give the approximate times **From** **To**

Are the above times based on UK or local times?

c) Quality of sleep **(circle one)**

Very poor				Very Good
1	2	3	4	5

FLIGHT DETAILS CONTINUED

d) Was your sleep disturbed? **(circle one)**

Frequently				**Not at all**
1	2	3	4	5

1.3 **ARRIVAL DETAILS**

Any problems with baggage? **(circle one)** Yes No

Were you met at the airport **or** did you have to make your own way to the hotel? **(delete one)**

APPENDIX IVb

PHASE 2 - PERFORMANCE MEASUREMENT STUDY

RETURN JOURNEY QUESTIONNAIRE

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

RETURN JOURNEY

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

RETURN JOURNEY

Name .... Date of Birth ....

Department .... Extension ....

1 GENERAL

1.1 Date of travel ....

1.2 Compared to you mental abilities at home, how would you rate your mental abilities on this trip

a) Immediately after arriving? **(circle one)**

Considerably Improved	Somewhat Improved	Unaffected	Somewhat Reduced	Considerably Reduced
1	2	3	4	5

b) Just before leaving to return home? **(circle one)**

Considerably Improved	Somewhat Improved	Unaffected	Somewhat Reduced	Considerably Reduced
1	2	3	4	5

RETURN JOURNEY CONTINUED

1.3 Was the climate at your destination **(circle one)**

Very pleasant		Comfortable		Unpleasant
1	2	3	4	5

1.4 Do you think the climate or cultural differences affected your mental abilities? **(circle one)**

Considerably Improved	Somewhat Improved	Unaffected	Somewhat Reduced	Considerably Reduced
1	2	3	4	5

1.5 If you are a smoker, was your tobacco consumption? **(circle one)**

Considerably Increased		Unaffected		Considerably Reduced
1	2	3	4	5

2 TRAVEL DETAILS

Original point of departure ....

Via ....

(Please highlight cities where change of aircraft required)

Scheduled Departure time .... Scheduled arrival time at final destination (local) ....

Actual Departure Time .... Actual arrival time at final destination (local) ....

Class of Travel .... (First/Business/Economy)

Smoking/ Non smoking seat ....

2.1 CHECK IN ARRANGEMENTS

How would you best describe your arrangements for getting to the airport and checking in for your flight? **(circle one)**

Relaxed/ No Problems				Crowded/ Long Queues/ Other Problems
1	2	3	4	5

2.2 FLIGHT DETAILS

a) Drinks consumed before and during flight

Tea/Coffee/Cola	......	cups/glasses
Fruit Juice/Soft Drinks/Mineral Water	......	glasses
Alcohol - Wine/Beer/Spirits	......	units

(1 unit = 1 glass of wine **OR** 1 half pint of beer **OR** 1/2 miniature of spirits)

b) Did you try to sleep on board **(circle one)** Yes No

If no, go directly to question 2.3

If yes, please give the approximate times **From** **To**

Are the above times based on UK or local times?

c) Quality of sleep **(circle one)**

Very poor				Very Good
1	2	3	4	5

d) Was your sleep disturbed? **(circle one)**

Frequently				Not at all
1	2	3	4	5

2.3 **<u>ARRIVAL DETAILS</u>**

Any problems with baggage? **(circle one)** Yes No

Were you met at the airport **<u>or</u>** did you have to make your own way to the hotel? **(delete one)**

Thank you for your help in completing this questionnaire.

APPENDIX V

PSION® ORGANISER

INSTRUCTION LEAFLET

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

Thank you for agreeing to take part in this phase of the study. You will be asked to use the Psion Organiser before, during and after your next five overseas trips, to answer a number of questions and to complete two performance tasks. Before departing on your first trip, we would like you to practice completing the questions and the tasks. This will not only get you used to using the organiser, but will also help stabilise your performance on the tasks before the study begins. **This is very important for our analysis.**

The results will be treated in **strict confidence**. We will show you how to use the organiser but enclosed are some instructions that you may find useful. Please read them carefully before you start and refer to them as necessary.

If you have any problems please contact:-

David Flower
Occupational Physician
0181 562 5674

What will I have to do each day?

1 Complete a sleep diary and two performance tasks when you wake up.

2 Complete a nap diary after each nap (if you have any).

3 Complete some questions and performance tasks in the middle of the day and before your evening meal.

4 Complete some questions at the end of each day.

GENERAL INFORMATION ON USING THE PSION

1 **What if something goes wrong?**

In the unlikely event that the organiser displays a message saying that the battery is too low, then this needs to be changed in the way you have been shown. It is important to have the new battery ready for insertion as the data will only be stored by the organiser for 20 seconds without power. If a longer time elapses, then all the data will be lost.

If the Psion displays a message saying that the memory is low, then please stop using the organiser and contact the department as soon as possible.

If you receive any other error message than please make a note of it. The message may ask you to press the **SPACE** key. Do this and then type **G** followed by the **ON** key and try again. If you have no luck, then contact the department.

If on the other hand, the message asks you to answer **YES** or **NO** then type **N** (for NO) and then **O** (for OFF) and contact the department. In all other cases contact the department directly.

2 **Is the Psion easily damaged?**

Do not be frightened of the Psion. You can not do any harm by pressing the keys but the data packs at the back of the organiser should not be removed.

3 **What if I want to demonstrate the Psion to a friend or colleague?**

It is better if you do not demonstrate the Psion because it will use up computer memory. However, if you do, then please use the number **99** when you are asked for an **ID** number so that we do not mistake those results as part of the main study.

HOW DO I SWITCH THE PSION ON AND OFF?

i) First slip the Psion out of its casing to reveal the keyboard. Use a quick downward motion to release the catch.

ii) To turn the Psion on press the key which is in the top left hand corner of the keyboard and is labelled **ON**.

iii) You will then be asked to give your **ID** number. This is the number that you will have been given by the department. Enter the number on the keyboard and press the **EXE** key (which is in the bottom right hand corner of the keyboard). The number keys have a blue background and the numbers are labelled above the key. (It is not necessary to use the shift key, just ignore the alphabetic labels on the number keys).

iv) If you make a mistake during number entry, then simply press the **DEL** key and the number will be erased so that you can try again.

v) After you have pressed the **EXE** key, a menu will appear. If you select the first item on this menu, **QUIT**, this will turn the organiser off.

vi) To select an item on the menu you may either type the first letter of the item eg **Q** for quit or alternatively you may use the **arrow keys** on the top row of the keyboard to move the cursor onto the item and then press the **EXE** key.

vii) You may adjust the brightness of the display using a small wheel on the side of the Psion.

THE TASKS

On what days do I need to perform the tasks for the study?

You will be asked to perform the tasks on:-

i) The day before departure overseas.

ii) For seven days after arrival at your destination (or for the duration of your trip overseas if this is shorter).

iii) On the day before your return home.

iv) For seven days after your return to the UK.

How often should I practice the tasks before the study?

Try to practice the tasks at least three times a day for one week before the start of the study. Do not worry if you mish a few tests, but the fewer you miss the better. **This practice is important.**

On subsequent trips you will only need to practice for one or two days before departure.

To practice the performance task, turn the Psion on, enter your code number and press **T** for test. Instructions on how to complete the task are outlined below.

How long will the task take to complete?

Once you are practiced the rating scales and tasks will take about five minutes or less.

What if I am interrupted during a task?

Once you have started a task session, you must try to continue with it. However, if necessary, you could pause whilst task instructions are being displayed. If you pause for more than a few minutes the display will turn off. Simply press the **ON** key and continue from where you left off.

RATING SCALES

These scales require you to rate how positive or negative you currently feel about various things. For example, you will be asked to rate your alertness, thus:-

- ________ +
*

You should first move the cursor (shown her as an asterisk) onto the horizontal line by using the up arrow key. Then if you are feeling alert, move the cursor towards the + end of the line by repeatedly pressing the right arrow key. Or if you are feeling drowsy, move the cursor towards the - end of the line by using the left arrow key.

The extreme right of the line represents the most alert that you ever feel and the extreme left, the most drowsy that you ever feel. The middle of the line represents a feeling halfway between these two extremes. Position the cursor at any point along the line and when you are satisfied that the cursor is in the position that represents your feelings, then press the **EXE** key.

Then do the same for the other rating scales:-

Alertness - using the procedure described above, rate how alert you currently feel.

Cheerfulness - similarly, rate how cheerful you feel at the moment.

Calmness - rate how calm you feel at that time.

When the above ratings have been completed, you will be asked to perform the performance tasks.

PERFORMANCE TASKS

Reaction time test

In this test, a * symbol will appear on the display in one of four positions. These four positions correspond to the positioning of the **M,T,W** and **R** keys:

*		.		*	display
	*		*		
M				R	keyboard
	T		W		

When the * appears you should press the key (**M,T,W** or **R**) which corresponds to the position of the * on the display. Respond as quickly as possible, but try to be accurate. Continue doing this until the test ends which will take about two minutes. Keep your eyes fixed on the small dot on the screen. To start the test press the **EXE** key.

Position your fingers so that your left middle finger is over the **M,** your left forefinger over the **T**, your right forefinger over the **W** and your right middle finger is over the **R**. Rest your thumbs on the base of the Psion.

At the end of the test, your results will be displayed and the Psion will then proceed onto to the second performance task.

Sternberg Memory Task

Our memory is involved when we perform all kinds of tasks in our daily lives. For example, we have to store pieces of information for a short time in order to make decisions about what action to take in a particular situation. The following performance task is a measure of this kind of memory process.

You will be required to memorise seven letters of the alphabet. When you have memorised these, press **EXE**. A series of letters will then appear one at a time in the middle of the display. If the letter that appears is one of the seven letters you memorised then press **T** for true, otherwise press **F** for false. Respond as quickly as possible, but try to be accurate.

Once again at the end of the test, you will receive some feedback about your performance. You will then automatically be taken back to the main menu. Select **QUIT** to turn the Psion off.

WHAT TASKS DO I NEED TO PERFORM?

i) You should complete a sleep diary followed by two performance tasks each day when you wake up from your main sleep. This is featured under **STARTDAY** and **TEST** on the Psion menu.

ii) You should record any naps that may be taken during the day and this is featured under **NAP** on the Psion menu.

iii) You should complete two performance tasks at lunchtime and again before your evening meal each day. These are featured under **TEST** on the Psion menu.

iv) At the end of each day, before going to bed, you should complete a final short set of questions and rating scales. These are featured under **ENDDAY** on the Psion menu.

SLEEP DIARY (STARTDAY)

When you wake up, turn the Psion on, enter your personal **ID** number and select **STARTDAY** from the menu. You will then be asked a number of questions about your sleep.

If you are asked to specify a time:-

i) First enter the hour by typing the appropriate number followed by the **EXE** key.

ii) Then enter the minutes by typing the appropriate number followed by the **EXE** key.

So to specify that you went to bed at 11.05 pm, you would use the following key sequence:-

23 EXE 05 EXE

If you make a mistake during number entry, you can use the **DEL** key to erase the number. However, once the **EXE** key is pressed, there is no going back.

SLEEP DIARY (STARTDAY) - CONTINUED

When you are asked **"I woke up ? times"**, simply type in a number which could replace the question mark and press **EXE**. For example, type **3** if you woke up three times.

When you are asked to rate the quality of sleep, use the arrow key to move the cursor onto the horizontal line and then use the left and right arrow keys repeatedly to move the cursor along the line to the position that best represents your feelings and then press the **EXE** key.

NAP DIARY (NAP)

Should you happen to take a nap at any time, please record the fact that you napped in the nap diary. After a nap, turn the Psion on, enter your personal **ID** number and select **NAP** from the menu. You will be asked to state when your nap started and when it finished in a similar way to the sleep diary.

END OF DAY RATINGS (ENDDAY)

At the end of each day (before going to bed) turn the Psion **ON**. Select **ENDDAY** from the menu and you will then be asked to rate:-

i) Your overall alertness, cheerfulness and calmness for the day. Do this for both work days and days off.

ii) Your overall effectiveness in the things that you have done during the day on both work days and days off.

iii) You will then be asked to record to what extent you have been subjected to mental demand, time pressure, have felt disorientated, experienced any appetite disturbance, felt physically tired, or experienced any other symptom during the day. If you have experienced any other symptoms, you should record these separately in order for us to identify these following your return.

END OF DAY RATINGS (ENDDAY) - CONTINUED

iv) You will then be asked to score how many units of alcohol you have consumed during the day. One unit is equivalent to one glass of wine or one measure of spirits or one 1/2 pint of beer.

v) You will then be asked whether you were working today. If the answer is yes, you will be asked to record the time you started and the time you finished work.

THANK YOU AND GOOD LUCK

APPENDIX VI

PSION® ORGANISER

SUMMARY OF INSTRUCTIONS

BRITISH AIRWAYS HEALTH SERVICES

TRAVEL FATIGUE STUDY

QUICK GUIDE TO USING THE PSION

Press **ON** to turn the Psion on, then type your **ID** number and press **EXE** to get to the main menu. Type **Q** at the main menu to turn the Psion off.

Type **S** (to get the cursor to **STARTDAY**) at the main menu to fill in a sleep diary when you get up in the morning.

Type **N** (to get the cursor to **NAP**) to fill in a nap diary following a nap.

Type **E** (to get the cursor to **ENDDAY)** to complete rating scales at the end of every day.

Type **T** (to get the cursor to **TEST**) to access the performance tasks.

All rating scales

Use the keys with arrows on them to position the cursor along the scale and then press **EXE**.

Reaction time test

Press **EXE** to start the test. An * appears in one of four positions. Press the key **(M,T,W or R)** which corresponds to the * on the display.

Sternberg memory test

Memorise the letters and press **EXE**. The letters then appear one at a time; if the letter that appears was one of the letters you memorised then press **T** (for **true**) otherwise press **F** (for **false**).

TRAVELLING WITH THE PSION

When you are flying please make sure you keep the Psion with you in your **HAND LUGGAGE.** During security checks at the airport please ensure that the Psion does **NOT** pass through the **metal detectors**, it is however safe for it to pass through the **x-ray machine**.

These precautions are vitally important in order that the data stored on the computer is not lost.

DAILY TIMETABLE

On rising

Press **ON** to turn the Psion on, then type your **ID** number and press **EXE** to get to the main menu.

Type S (to get to **STARTDAY**) at the main menu to fill in a sleep diary.

Type **T** (to get to **TEST**) to complete the performance tasks

Lunchtime (12 - 2 pm)

Press **ON** to turn the Psion on, then type your **ID** number and press **EXE** to get to the main menu.

Type **T** to complete the performance tasks.

Before evening meal (6 - 8 pm)

Press **ON** to turn the organiser on, then type your **ID** number and press **EXE** to get to the main menu.

Type **T** to complete the performance tasks.

At end of day, before going to bed

Press **ON** to turn the organiser on, then type your **ID** number and press **EXE** to get to the main menu.

Type **E** (to get to **ENDDAY**) at the main menu to complete the rating scales for the day.

Nap diary

Should you take a nap at any time during the day, type **N** (to get cursor to **NAP**) and fill in the nap diary.

APPENDIX VII

PHASE 1 - TRAVELLER PROFILE STUDY

QUESTIONNAIRE COMMENTS

APPENDIX VII PHASE 1 - TRAVELLER PROFILE STUDY QUESTIONNAIRE COMMENTS

Subject No.	Question 2.6 (e)	Question 2.7 (Medication)	During flight	After flight
1	-	-	relax	NSP
2	-	-	-	exercise
3	-	-	mod alcohol	alcohol +
4	migraine	-	-	NSP
5	-	avomine	-	-
7	-	-	-	-
8	-	-	NTZ	1 day rest
9	-	-	fluids	-
10	-	temazepam	-	-
11	-	-	NTZ	NSP
12	-	-	-	-
14	-	-	-	-
17	-	-	NTZ	work
18	-	nitrazepam	sleep	NSP
19	nausea	-	exercise	exercise
20	-	nitrazepam	sleep	exercise
21	-	-	-	NSP
22	-	-	-	NSP
23	-	-	-	-
24	-	-	relax	work
25	irritation	-	fluids	exercise
26	-	-	sleep	-
27	nausea	-	sleep	NSP
101	dietary	-	relax	relax
102	-	temazepam	-	-
103	-	-	NTZ	NSP
104	-	-	exercise	NSP
105	-	-	-	NSP
106	-	-	fluids	NSP
107	-	-	reading	NSP
108	-	-	NTZ 12 hrs in advance	-
109	-	-	NTZ	NSP
110	-	-	-	-
112	-	-	-	NSP
113	-	-	sleep/fluids/ exercise	nap then NSP
114	-	stugeron	-	-
115	-	stugeron	sleep	-

116	-	-	-	-
117	-	-	exercise	NSP
118	-	-	sleep	NSP
119	-	-	exercise	-
120	-	-	sleep/fluids	nap then NSP
121	-	-	exercise	exercise/NSP
122	-	-	-	-
123	-	promethazine	-	-
124	-	-	fluids	-
125	-	-	-	-
126	-	-	-	-
127	-	-	-	-
128	-	-	-	NSP
129	-	-	-	-
130	-	temazepam	-	-
131	-	-	fluids/exercise	NSP
132	-	travel sickness medication	-	-
133	-	-	relax	NSP
134	bowel disturb	-	-	-
135	physical alertness	-	-	-
136	-	-	-	-
137	-	sleeping tab	-	-
138	-	-	NTZ	NSP
139	bowel disturb	-	fluids/rest	NSP
140	-	-	sleep	NSP
142	-	-	-	-
143	-	-	-	NSP
144	abdo pain	-	-	-
145	-	-	-	-
146	bowel disturb	-	-	-
147	-	-	NSP	NSP
148	-	-	-	NSP
149	-	-	sleep	NSP
150	-	-	-	-
151	headache	-	fluids/rest	NSP
152	-	-	-	-
153	-	-	-	-
154	-	temazepam	-	-
155	-	-	-	-

156	bowel disturb	-	-	NSP
157	-	-	fluids	NSP
158	-	-	sleep	NSP
159	-	-	NTZ	NSP
160	-	-	sleep	sleep
161	-	-	sleep	NSP
162	delayed physical tiredness	-	-	-
163	-	-	sleep	sleep
164	-	-	NSP	NSP
165	thirst	-	-	NSP
166	-	-	-	-
167	thirst	yes, ? what	audio/film	sleep
168	-	-	fluids	NSP
169	-	-	sleep	-
170	-	-	-	-
171	-	-	sleep	NSP
172	-	vitamins	fluids/exercise	NSP
173	-	-	-	-
174	-	-	NSP	NSP
175	-	-	-	NSP
176	-	-	fluids/sleep	-
177	-	-	-	-
178	-	-	sleep	sleep
179	-	temazepam	-	-

Subject Numbers - Nos 1 - 27 relate to subjects also participating in Phase 2, the Performance Measurement Study.

- Nos 101 - 179 relate to subjects only participating in Phase 1, the Traveller Profile Study.

NTZ - New Time Zone
Subject changes watch to NTZ immediately on boarding the aircraft.

NSP - Normal Sleep Pattern
Subject adopts sleep/wake cycle appropriate to the new time zone immediately on arrival at destination.

APPENDIX VIII

PHASE 2 - PERFORMANCE MEASUREMENT STUDY

NUMBER OF TRIPS COMPLETED

BY EACH SUBJECT

APPENDIX VIII PHASE 2 - PEFORMANCE MEASUREMENT STUDY - NUMBER OF TRIPS COMPLETED BY EACH SUBJECT

Subject No.	No. of Trips Completed	No. of Trips with Data
2	5	5
5	5	5
7	5	5
8	4	4
9	4	4
10	5	5
11	5	5
12	5	5
14	2	2
17	5	5
18	3	3
19	5	5
20	5	4
21	4	4
22	5	4
23	2	2
24	4	4
25	5	5
26	5	5
27	5	5