

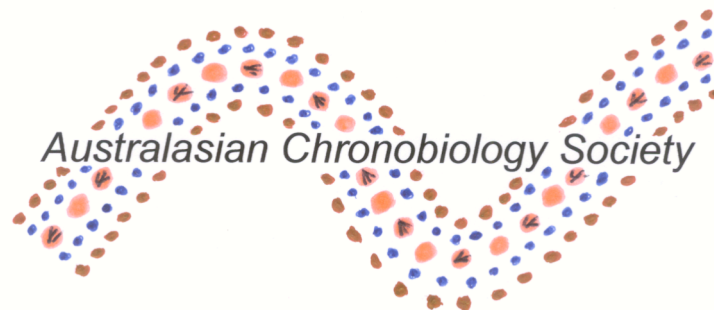
Living in a 24/7 World:

The impact of circadian disruption on sleep, work and health

Australasian Chronobiology Society
7th Annual Meeting

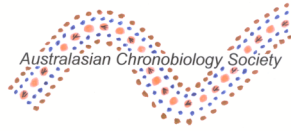
4 – 5 September 2010

University of South Australia, Adelaide, Australia



Citation

Heath G, Sargent C, Darwent D, Ferguson SA, Kennaway DJ, Hampton LK, Matthews RW, Roach GD (2010). Subjective mood is influenced by sleep-related and circadian processes in a forced desynchrony protocol with severe sleep restriction. In: Sargent C, Darwent D, Roach GD (Eds). *Living in a 24/7 world: The impact of circadian disruption on sleep, work and health*. Australasian Chronobiology Society, Adelaide, Australia, pp. 7-11.



Chapter 2

Subjective mood is influenced by sleep-related and circadian processes in a forced desynchrony protocol with severe sleep restriction

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Aims: Studies show subjective mood declines when sleep is severely restricted to 4-5h per night. In addition, mood follows a circadian rhythm such that subjective mood is lowest around the circadian nadir. These findings are important for shiftworkers who often report severe sleep restriction and are subject to circadian disruption. The current study aims to examine the effect of prior wake and circadian phase on subjective mood when sleep is severely restricted to the equivalent of 4h of sleep opportunity per 24-h day.

Methods: 14 healthy males (21.8 ± 3.8 yr) lived in a time isolation laboratory for 12 consecutive days. Participants were scheduled to 3 x 24-h adaptation days (16-h wake, 8-h sleep opportunity), followed by 7 x 28-h forced desynchrony days (23.3-h wake, 4.7-h sleep opportunity). Total Mood Disturbance (TMD) was assessed every 2.5h during wake using the Profile Of Mood States scale. Core body temperature was continuously recorded with rectal thermistors and used to determine circadian phase.

Results: A significant effect of prior wake was found for TMD ($p < .001$). Scores for TMD increased with duration of wakefulness. A significant effect of circadian phase was found for TMD ($p < .001$). TMD scores were highest around the circadian nadir and lowest around the circadian acrophase. No interaction effects were found.

Discussion: These findings suggest mood is influenced by sleep-related and circadian processes separately in a controlled laboratory environment when sleep is severely restricted. Field based research investigating sleeping patterns and mood in shiftworkers would provide further understanding of how other factors such as work and family mediate between sleep restriction/circadian disruption and mood in an external environment.

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Introduction

It is generally accepted that sleep plays a restorative role in general well-being and daily functioning.¹¹ Forced desynchrony studies (FD) have shown that the duration of prior wake and circadian phase affect mood.^{2,7} Mood tends to decline with increasing duration of prior wake and reaches its lowest point around the circadian nadir. In these studies the ratio of sleep and wake was kept within a

normal range (i.e. the equivalent of 8h sleep per 24-h day), however, there is evidence to suggest that sleep dose also alters mood. For example, participants who are subject to severe sleep restriction (i.e. 4-5h sleep opportunity per night) for one week report higher levels of anxiety, depression, fatigue and confusion than controls provided with a normal sleep opportunity of 8h per night for one week.⁵ To date there have been no studies

employing an FD protocol to assess mood when sleep is severely restricted. Therefore, the current study examined the influence of prior wake and circadian phase in an FD protocol with severe sleep restriction (i.e. 4h per 24-h day).

Methods

Participants

Fourteen healthy males (age: 21.8 ± 2.5 yr, mean \pm SD) participated in this study. All participants were in the healthy weight range (BMI 22.4 ± 2.3 kg/m²), were non-smokers, with normal sleeping patterns. Participants did not have any medical conditions and were not taking any medications. Participants were excluded from the study if they were shiftworkers, had recently travelled through time zones or reported a high caffeine or alcohol intake. Ethics approval for this study was obtained from the University of South Australia Human Ethics Committee. Written informed consent was obtained from all participants and the research methods conform to the guidelines established by the National Health and Medical Research Council of Australia

Measures

Mood was assessed using the Profile of Mood States (POMS) [9]. POMS assesses transient mood states by asking participants to respond to 65 adjectives. Participants completed a 5-point Likert-type scale ranging from ‘not at all’ to ‘extremely’. POMS measures five negative mood domains: Tension-Anxiety (T-A), Depression-Dejection (D-D), Anger-Hostility (A-H), Fatigue-Inertia (F-I) and Confusion-Bewilderment (C-B) and one positive mood domain, Vigour-Activity (V-A). A Total Mood Disturbance (TMD) score is computed by summing the negative domain scores and subtracting the positive domain score. Higher scores indicate greater mood disturbance.

Core body temperature (CBT) was recorded continuously in 1-min epochs

with indwelling rectal thermistors (Steriprobe 491B; Cincinatti Sub-Zero Products, Cincinnati, Ohio, USA). The thermistors were connected to a Mini-Mitter datalogger (Bend, OR).

Sleep was monitored using polysomnography. Prior to each sleep opportunity, electrodes were attached to the face and scalp using a standard montage. Sleep was scored in 30-s epochs in accordance with accepted criteria.¹⁰ Sleep efficiency was calculated as the percentage of time in bed spent asleep.

Protocol

The participants were required to live in a time isolation laboratory for 12 consecutive days. The first three days were 24h in length and consisted of a 16-h wake episode during the day followed by an 8-h sleep opportunity at night. These days were used to train participants on the POMS and to allow participants to familiarise themselves with the laboratory environment. The FD protocol began upon waking after the third night and consisted of seven 28-h ‘days’, each with a 23.3-h wake episode and 4.7-h sleep opportunity (this is equivalent to a 4-h sleep opportunity per 24-h day). During the wake episodes the POMS was administered every 2.5h as part of a 1-h test battery (i.e. 9 test batteries in total). The first test battery began 1.5h after scheduled wake up time.

Data reduction and statistical analysis

CBT data from six FD days (2-7) were used to generate circadian phase estimates for each participant. The generation of phase estimates from CBT data was a 4-step process: (i) clean the raw CBT data, (ii) de-mask for physical activity and sleep/wake, (iii) fit a cosine equation to the de-masked CBT data, and (iv) assign a circadian phase estimate (i.e. 0-360 degrees) to each minute of the FD portion of the protocol using a resultant cosine equation.⁴

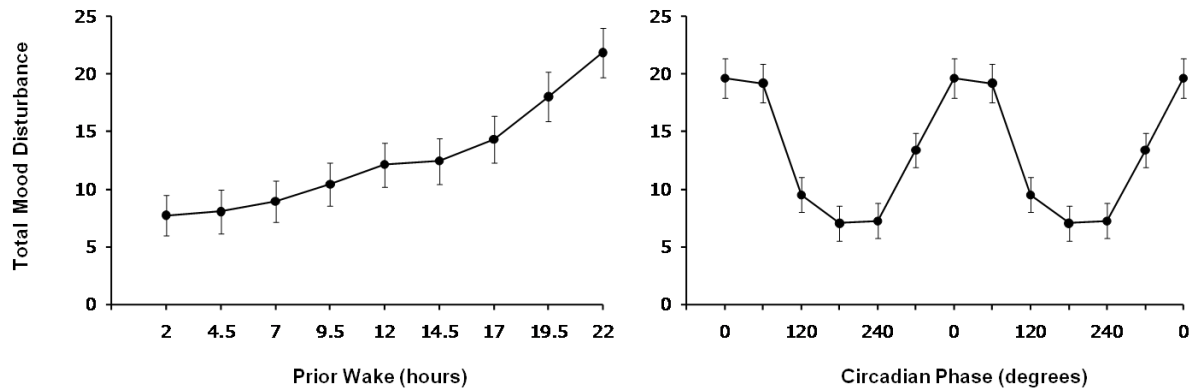


Figure 1. Main effects of prior wake (left) and circadian phase (right) on Total Mood Disturbance. Circadian phase data are double plotted. Values are mean \pm SEM.

Individual data points were grouped according to circadian phase and level of prior wakefulness. For analysis of the circadian component, a bin width of 60 degrees (~4h) was selected. For analysis of the prior wake component, nine levels of prior wake were identified that corresponded to the midpoint of each test battery. The main and interaction effects of prior wake and circadian phase on TMD and the six mood domains were analysed using linear mixed model analysis. To control for any differences in sleep duration across the study days, sleep efficiency was included as a covariate in all analyses.

Results

Total Mood Disturbance

There was a significant main effect of prior wake for TMD, $F_{(8, 118)} = 18.6$, $p < .001$ (Figure 1). TMD scores rose progressively with increasing duration of prior wake. There was a significant main effect of circadian phase for TMD, $F_{(5,171)} = 37.7$, $p < .001$ (Figure 1). TMD was

greatest at the circadian nadir and lowest at the acrophase.

Negative mood domains

There was a significant main effect of prior wake for all negative mood domains except A-H (Table 1). Scores on the negative mood scales were lowest at the first testing session and increased over the wake period. A significant main effect of circadian phase was found for all of the negative mood domains (Table 1). Scores on the negative mood scales were highest at, or just after, the circadian nadir and lowest at, or just after, the acrophase.

Positive mood domains

There was a significant main effect of prior wake for the positive mood domain of V-A (Table 1). Scores for V-A were highest at the first testing session and reduced over the wake period. There was a significant effect of circadian phase for V-A, such that scores were highest around the circadian acrophase and lowest around the circadian nadir.

Table 1. Main effects of prior wake and circadian phase on mood domains.

Mood Domain	Prior Wake			Circadian Phase		
	F	df	p	F	df	p
Tension-Anxiety (T-A)	4.1	8,91	<.001	10.6	5,146	<.001
Depression-Dejection (D-D)	3.1	8,90	<.01	6.3	5,149	<.001
Anger-Hostility (A-H)	2.5	8,68	.053	3.8	5,104	<.01
Fatigue-Inertia (F-I)	20.3	8,97	<.001	42.5	5,183	<.001
Confusion-Bewilderment (C-B)	14.0	8,123	<.001	30.2	5,171	<.001
Vigour-Activity (V-A)	12.3	8,112	<.001	38.3	5,190	<.001

Note: Denominator degrees of freedom are displayed as adjusted by SPSS using a Satterthwaite correction.

Discussion

The current study revealed mood is affected by sleep-related and circadian processes independently when sleep is severely restricted. Participants became increasingly anxious, depressed, confused, more fatigued and felt less active with increasing duration of prior wake and around the circadian nadir; however, the level of mood disturbance found did not reach clinical significance.⁹ No interactions of prior wake and circadian phase on mood were found.

In contrast to previous FD studies, the current study included severe sleep restriction in the protocol. Participants in this study remained awake for 23.3h and were given a sleep opportunity of 4.7h, which is equivalent to 4h of sleep per 24-h day. A previous FD study found that mood (cheerfulness and happiness) was not significantly affected by prior wake; however there was a trend for mood to decline over the wake period.² A subsequent FD study found depression was not significantly affected by duration of prior wake.⁷ However in both of these studies participant's sleep/wake was kept in line with a normal sleep ratio of 1:2 (i.e. the equivalent of 8h sleep per 24-h day). The severe sleep restriction and lengthy duration of prior wake in the current study may explain why we found a significant deterioration in mood and the previous studies did not. In addition, the previous FD studies used measures other than POMS to assess mood. Future studies should assess mood with POMS in an FD protocol with a normal sleep/wake ratio as this would allow for a direct comparison between the sleep doses.

In line with previous research,^{2,7} the current study found mood displayed a circadian rhythm. Participants reported feeling more depressed, anxious, confused, angry and fatigued around the circadian nadir than they felt around the

acrophase. Feelings of activity were lowest around the circadian nadir. Therefore, individuals who are required to remain awake throughout the biological night such as shiftworkers are likely to find their mood deteriorates during the early hours of the morning. The deterioration in mood may be compounded for shiftworkers due to the severe sleep restriction they often experience.¹ Indeed, shiftworkers often report mood disturbances such as anxiety and depression.⁶

The results of this study suggest severe sleep restriction, duration of prior wake and circadian phase impact on mood. Therefore, the current study has practical significance not only for shiftworkers who report severe sleep deprivation and circadian disruption¹ but also for any individuals who are deprived of sleep and have long durations of wakefulness. Mood states have been associated with various outcomes. Negative mood states have been found to influence job attitudes and behaviours³ and psychological well-being.¹¹ In contrast, positive mood such as happiness and thinking optimistically may play a role in the prevention of cardiovascular disease.⁸ A limitation of laboratory studies is that participants are not in their natural environment. Laboratory studies are unable to ascertain if other factors such as social, family and work pressures mediate the relationship between sleep restriction, circadian disruption and mood disturbances. Field studies investigating the mood of shiftworkers may enhance our understanding of how sleeping patterns and circadian disruption effect mood in this population.

Acknowledgements

The authors gratefully acknowledge the financial support of the Australian Research Council.

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