FIRE CODE REFORM

Technical Report
FCRC-TR 97- 13

The Effects of Sleep Inertia on Decision-Making Performance

FCRC Project 4
Fire Safety System Design Solutions
Part A – Core Model & Residential Buildings

Fire Code Reform Research Program
February **1997**

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Background

The Fire Code Reform Research Program is funded by voluntary contributions from regulatory authorities, research organisations and industry participants.

Project 4 of the Program involved development of a Fundamental Model, incorporating fire-engineering, risk-assessment methodology and study of human behaviour in order to predict the performance of building fire safety system designs in terms of Expected Risk to Life (ERL) and Fire Cost Expectation (FCE). Part 1 of the project relates to Residential Buildings as defined in Classes 2 to 4 of the Building Code of Australia.

This Report was relevant to the project activities in support of the Model's development and it is published in order to disseminate the information it contains more widely to the building fire safety community.

Acknowledgements

Since inception of the Fire Code Reform Research Program in 1994 the Australian Building Codes Board has been its principal financial contributor. Substantial funds have also been provided by Forest and Wood Products Research and Development Corporation and generous contributions have been received from a number of industrial and financial entities and individual donors.

The Board and management of Fire Code Reform Centre Ltd acknowledge with sincere thanks receipt of all these financial contributions. The company also acknowledges the kind permission of the author(s) and the Centre for Environmental Safety and Risk Engineering at Victoria University of Technology to re-produce and publish this document.

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THE

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Submitted to *Journal cf Sleep Research,* May 1997.

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SUMMARY

Sleep inertia, the performance impairment that occurs immediately after awakening, has not previously been studied in relation to decision making performance. Twelve subjects (18-30 years) were polygraphically monitored in the sleep laboratory for one night. Subjects were abruptly awoken by a fire alarm twice during the night, once during SWS and once during REM sleep. Once awoken, subjects remained awake for 30 minutes and completed various tasks. Decision making performance was measured over 10 three minute trials using the 'Fire Chief' decision making task. Subjective ratings of sleepiness (Karolinska Sleepiness Scale) and ratings of 'Clear Headedness' were obtained immediately following arousal and every six minutes thereafter. Findings revealed that decision making performance was impaired following S WS for 12 minutes, and following REM sleep during the time periods O-3 and 9-12 minutes as compared to baseline performance. The greatest impairments were within the first three minutes after arousal, whereby subjects were performing at only 5 1% (SWS awakening) and 65% (REM awakening) of their optimum performance. Subjects also reported being significantly sleepier and less clearheaded following both SWS and REM arousal compared to baseline, with -impairment being longer following REM arousal than SWS arousal. The main finding from this study is that within the first 3 minutes after abrupt nocturnal awakening, decision making performance may be as little as 5 1% of optimum. In order to generalize this finding to real-life situations, further research is required concerning the effects of continuous noise, emotional arousal and physical activity on the severity and duration of sleep inertia.

KEY **WORDS:** sleep inertia, decision making, sleepiness, clear headedness, performance.

ACKNOWLEDGMENTS: The assistance of Dr Mary Omedei with helpful advice at various stages of this study was much appreciated. Thanks also to Dr Bernadette Hood for useful comments on the manuscript.

INTRODUCTION

Immediately upon awakening from sleep, sleep inertia effects inertia refers to the decrease or impairment of performance that occurs immediately upon awakening from sleep compared to that prior to sleep (Bonnet, 1993; Bonnet & Arand, 1995; Dinges et al, 198 1). This apparent impairment, whereby the subject may be very sleepy, confused and/or disorientated, has been reported by a number of researchers (Balkin & Badia, 1988; Bonnet, 1983, 1993; Bonnet & Arand, 1995; Dinges, 1990; Dinges, 1992; Dinges, et al., 198 1; Dinges et al, 1985; Dinges et al, (1987); Kleitman, 1963; Mullington & Broughton, 1994; Naitoh, 198 1; Pivik, 199 1). Its manifestation is most evident and dramatic when awakening from sleep is abrupt, regardless of whether the sleep occurs at night or during a daytime nap (Dinges, 1989; Dinges et al., 198 1).

Sleep inertia can be described as a rising trend in alertness, reflecting a wake up effect. This occurs despite the fact that the sleep from which a person has awoken may have fully dissipated their sleep need (Folkard & Akerstedt, 1992). The waking up process is gradual, demonstrating that the recently asleep brain of a person experiencing sleep inertia is not necessarily sleep starved but is struggling to move from a sleep state toward full alertness (Balkin & Badia, 1988).

While sleep inertia is typically modest and short lived in normal, non sleep deprived individuals (Dinges, 1990), there is no agreement about its actual duration. Dinges (1990) suggested that it can endure from one minute to 20 minutes. Wilkinson and Stretton's (197 1) nocturnal study found that sleep inertia endured for up to 15 minutes. In contrast, Dinges et al., (198 1) found that it only lasted from one to five minutes. Akerstedt et al., (1989) suggested that although sleep inertia is normally rapidly dissipated, it appears that it may be extended under certain circumstances. For instance, it can be more severe if arousal from sleep occurs during the first half of the night or during SWS (Dinges 1991).

Work on sleep inertia has generally been based on the assumption that the stage prior to awakening is a very important consideration (Dinges et al., 1985). A number of studies have found that sleep inertia was significantly more severe when subjects were awoken from NREM sleep, especially SWS, as opposed to REM sleep (Akerstedt et al., 1989; Bonnet, 1983; Broughton, 1989 Dinges, 1989; Dinges, 1990; Dinges et al., 1985; Mullington & Broughton, 1994; Pivik, 1991; Stampi, 1989).

The significance of the sleep inertia effect is such that it has also been incorporated into a number of theoretical models. Folkard and Akerstedt (1992) have devised a three process model of the regulation of alertness and sleepiness which aims to predict alertness ratings at any given point in time and on any given sleep/wake schedule. The model incorporates Process W, which is initiated at awakening, and refers to the 'waking up' effect. Achermann & Borbely's (1992) model proposes that homeostatic and circadian processes as well as a sleep inertia component account for experimental data of alertness ratings.

Balkin and Badia (1988) conducted a study on the relationship between sleep inertia and sleepiness and found no conclusive evidence suggesting that sleep inertia is qualitatively different from typical sleepiness. This is consistent with the suggestion that sleepiness is not necessarily a response to sleep need, but rather, -may reflect the incomplete disengagement of sleep processes (Pivik, 1991).

Previous studies of sleep inertia have used performance tasks such as reaction time and arithmetic Badia 1988, Dinges et al 1981, 1985, 1987; Mullington & Broughton 1994; Webb & Agnew 1964, Wilkinson & Stretton 1971), grip strength (Jeanneret & Webb 1963, Tebbs & Foulks 1966) or a variety of memory tasks (Bonnet 1983, Stones 1977, Tassi et al 1992). There is no published research on how sleep inertia may influence decision making.

The potential impact of sleep inertia on decision making has significant implications as people are called upon to make complex decisions soon after awakening in a variety of field settings. This includes emergency workers and people awoken by a disaster e.g. fire and flood. Decision making is a complex cognitive process. It involves the accurate search & appraisal of information, understanding the options and choosing the best from the available alternatives. The latter involves evaluating probable consequences of an action. During this process the person continues to seek new information and reevaluate old information, and when the required level of confidence is reached a final decision is made (Festinger 1964).

The effect and duration of impaired decision making due to sleep inertia is unknown. As there is no consensus on the duration of sleep inertia, which may vary depending on the type of task, it was not possible to be definitive in predicting how long the effect would last for in relation to decision making. Consideration of the studies discussed earlier suggest that a time period of 30 minutes should span the complete duration of sleep inertia.

This study represents the first step in evaluating possible impairment in decision making performance due to sleep inertia. Specifically, the study investigates the time required to achieve waking levels of decision making performance, and documents subjective ratings of sleepiness and clear headedness during the postulated sleep inertia period. It also compares the level of performance decrement, subjective sleepiness and clear headedness when awakening from S WS compared to REM sleep.

METHOD

Subjects

Twelve subjects, aged between 18-30 years (mean age 22.3, standard deviation 3.6) participated in this study. They were acquaintances of the researchers and students from Victoria University who volunteered in response to an internal advertisement. They reported themselves to be in good health and normal sleepers. All subjects received $10 (Australian) to cover transport expenses to the university sleep laboratory.

Apparatus

A Grass model 7 polygraph/paper chart recorder was used to record relevant polysomnographic measures. The alarm to arouse sleepers was a recording of a standard fire alarm presented at a volume of 75dB at the pillow. Subjects slept in a single bedroom adjacent to the sleep recording apparatus.

The performance measure used was 'Fire Chief decision making task (Omodei and Wearing (1993a, 1993b), Version 2.2) which was installed on an IBM clone 386 computer in the bedroom. This is an interactive computer administered task which has been programmed to capture the essential attributes of real life decision making situations. Subjects are required to assume the role of a chief fire officer responsible for fire control in a specified area comprising various types of landscape elements and fire appliances (trucks and helicopters). The subjects are able to control the spread of the simulated fires, which move according to the wind direction, by dispatching firefighting appliances to drop water on them. Refilling of the appliances is required at local dams.

More specifically, a relatively simple Fire Chief forest scenario was used comprising trees, five scattered dams, 10 houses, one helicopter and one truck available for use. Two developed fires were specified for the start of each trial. One spot fire was specified in the middle of the trial. All the events, including the changes in wind strength and direction and number of fires, were preset. Hence, fires were programmed to develop under conditions of fixed changes in both strength and wind direction and subjects were warned that the wind strength and direction would change at various times throughout the trials. All 10 trials (each of 3 minutes duration) were programmed to have the same characteristics to ensure as much consistency as possible across the trials. However, in each trial the houses and dams were positioned differently so they appeared different. The task involves easy to remember and easy to use mouse and keyboard procedures.

The Karolinska Sleepiness Scale (KSS) was used to obtain a subjective measure of sleepiness. It is a nine point scale which ranges from 'extremely alert' (1) to 'extremely sleepy, fighting sleep' (9). KSS ratings have been shown to consistently relate to polysomnographic variables, (Akerstedt & Gillberg, 1990) and performance tasks (Gillberg, et al., 1994).

The 'Clear Headed' rating scale is an unvalidated scale constructed for this study to determine how clear headed subjects feel after arousal at particular points in time. It is a five point scale which ranges from 'extremely clear headed' (1) to 'not at all clear headed' (5).

Procedure

Each subject spent one night in the sleep laboratory at Victoria University. Subjects arrived at the sleep laboratory several hours before their usual bed time. Subjects were randomly assigned to either a morning baseline group or an evening baseline group. Subjects in the evening baseline group were first given instructions and a demonstration of the Fire Chief decision making task, which was followed by a one hour session on the task to ensure familiarity and control for practice effects. Subjects *were* then prepared for the polysomnograph recordings. This procedure involved the standard attachment of 13 surface electrodes to the face and scalp to record brain waves, eye movements and muscle tension. (Rechtschaffen & Kales 1968). Subjects were then required to complete the baseline trials of the Fire Chief task, the KSS and the clear headed rating. A break of at least one hour was placed between the practice and baseline trials. This was to ensure that the first trial during baseline would not be experienced as a continuation of the practice trials. This was important as first trials on Fire Chief are likely to show a " warm- up " decrement (Omodei, personal communication). The decision making task consisted of 10 three minute trials. Further, every six minutes before performing the next trials, subjects filled out the KSS and clear-headed rating. The trials presented for familiarisation were different to those used for experimentation.

In order to avoid possible systematic bias arising from the baseline trials always preceding the sleep inertia trials, half the subjects were assigned to a morning baseline group. They were first attached to the polysomnograph and then they were familiarised with the task before they went to bed. They performed their baseline trials in the morning after breakfast and prior to leaving. All subjects were given the opportunity to listen to the alarm prior to going to sleep.

All arousals were sudden. For each subject, the alarm was activated twice during the night; once during SWS (stage 4 where possible and if not, stage 3) and once during REM sleep. The order of waking from these two stages was counterbalanced across subjects. A minimum of 80 minutes of sleep occurred before each subject was awoken.

Stage scoring was carried out according to the method of Rechtschaffen and Kales (1968). When the subject reached the desired sleep stage, as indicated by the electrophysiological records, the alarm was activated by the researcher. When the subject reached full EEG wakefulness, the researcher turned off the alarm and then entered the bedroom and turned on a very dim light. The subject was immediately required to fill out the KSS and clear headed rating, which only required a few seconds. These responses were further required after 6,12, 18, 24 and 30 minutes. The computer was moved to the subject so it was unnecessary for them to leave the bed. Each subject was required to perform 10 three minute trials on the decision making task. Their performance score was given to them after each three minute trial. When the session was completed the subject was allowed to return to sleep until the second awakening. After the second awakening, subjects were allowed undisturbed sleep until morning.

The experiment was approved by the Victoria University Human Experimentation Ethics Committee.

RESULTS

All 12 subjects were able to fall asleep, and all subjects were able to fall asleep again following the first arousal. With regard to SWS arousals, it was possible to wake two thirds of the subjects from stage four, and the remaining subjects had to be woken from stage three.

Decision Making Performance

Data Analysis

Sleep inertia was operationally defined as a decrement in decision making performance tested immediately after waking from nocturnal sleep (SWS and REM sleep) compared to baseline performance.

Overall objective decision making performance scores were automatically generated by the 'Fire Chief program. The score corresponds to the value of the landscape segments, that is, the percentage of trees and houses which are still unburnt at the end of the trial. It is important to understand that in the Fire Chief program a performance score (percentage saved) is generated from each trial even if *no* decisions are made. These were subtracted from sleep arousal means in order to determine the true amount *actively* saved during each trial by subjects. If subjects made no attempt to make decisions during Trial 1 (O-3 minutes), they would still score 36.32%, and so this figure was subtracted from their baseline, SWS and REM arousal mean scores obtained during Trial 1. Similarly, the no response score for Trial **2** was 38.44%, Trial 3 was 33.33%, Trial 4 was 36.59% and Trial 5 was 33.58%.

The data for this study were analysed using SPSS for Windows. One tailed paired t-tests (df = 11) were employed for the testing of differences between decision making performance under different experimental conditions. In order to help control for alpha inflation (and hence reduce the likelihood of making Type 1 errors) it was decided not to do planned statistical analyses across the full 30 minutes. On the basis of previous sleep inertia literature (see introduction) a duration of 12 minutes was felt to be suitable initially. Thus for each set of comparisons of decision making scores, four t-tests (one for each three minute time block) were required. The Bonferroni adjustment was applied from an alpha level of .05 and thus an alpha of .0125 was employed.

Table 1.

Means, standard deviations, t-test results, decrement (%) and relative performance capability (%) for decision making performance comparing baseline, SWS arousal, and REM sleep arousal.

BASELINE			SWS Arousal		REM Arousal		BASELINE VS SWS				BASELINE VS REM				SWS VS REM	
Time block (mins)	Mean	SD	Mean	SD	Mean	SD	t	p	Decrement (%)	Relative performance capability %	t	p	Decrement (%)	Relative performance capability (%)	t	p
(a)																
o-3	32.57	5.82	16.49	7.96	21.23	4.83	5.06	.000*	16.08	SO.63	4.98	.000*	11.34	65.18	-2.51	.014
3-6	43.19	12.48	32.36	11.81	35.65	12.74	2.98	,006'	10.83	74.92	1.70	.059	7.54	82.54	-0.98	,174
6-9	38.93	10.08	26.48	10.12	37.73	10.99	3.00	.006*	12.45	68.02	.042	.34	1.2	96.92	-2.42	.017
9-12	38.79	11.20	28.78	8.97	28.90	6.25	2.58	.0125*	10.01	74.19	2.98	.006*	9.89	74.50	-0.07	,472

Note: degrees of freedom = I 1, N=12. * significant at .0125 level

Performance **Results**

The results in Table 1 indicate that decision making performance after SWS arousal was significantly lower than baseline performance in each of the four time blocks during the first 12 minutes after awakening. It is noted that the largest decrement for post SWS arousal was within the first three minutes, at which time subjects were only performing at 5 1% of their optimum performance. Given that all time blocks within the first 12 minutes showed significant differences between SWS and baseline decision making performance, it was of interest to see whether this decrement was maintained for subsequent time blocks. Thus, a post hoc analysis was conducted to investigate the decrement during the period 12- 15 minutes post arousal. During this time period, the baseline decision making performance mean was 36.41% (SD = 14.99) and the post SWS performance mean was 35.07% (SD = 14.68). Hence, at 12-15 minutes, subjects awoken from SWS were performing at 96.32% of their optimum performance, Decision making performance following SWS arousal at this time interval was not significantly different from the baseline decision making performance ($t(11) = 0.64$, $P = .27$).

Following REM sleep arousal, decision making performance was significantly lower than baseline performance for the first three minutes after awakening (see Table 1). The highest decrement in decision making performance occurred within the first three minutes following REM arousal where subjects were only performing at 65% of their optimum performance. However, for the subsequent 3-9 minute time period there were no significant differences between decision making performance after REM sleep arousal compared with baseline. In the next time period (9-12 min), decision making performance was significantly lower after REM sleep arousal compared to baseline. Given the results, a post hoc analysis was conducted to investigate the difference in decision making performance between post REM sleep and baseline performance for the period between 12-1 5 minutes. The mean baseline performance was 36.08% (SD = 14.99) and the mean for the post REM sleep arousal was 37.5 1% (SD = 8.93). There was no significant difference in these scores (t(1 1)= -.24,

Comparisons were also made between decision making performance following SWS and REM sleep. With alpha set at .0125, the results indicate that there were no significant differences between decision making performance after SWS compared with performance following REM sleep arousal (see Table I). Although not significant, subjects did show a performance decrement following SWS during all the time blocks and particularly for the O-3 and 6-9 minute time blocks.

Subjective Sleepiness Ratings (KSS)

Data Analysis

One tailed paired t-tests were also employed to determine the differences between subjective ratings of sleepiness taken every six minutes during small breaks in performing the decision making task . The full 30 minutes post arousal was considered, covering six time periods. Bonferroni adjustment was applied from an alpha level of .05 for the t-tests, with alpha thus set at .008. Results are presented in Table 2.

Table 2.
Means, (and standard deviations), t values and p values for subjective sleepiness ratings (KSS) comparing baseline with post **SWS** arousal ratings and post REM sleep arousal ratings.

	BASELINE		SWS Arousal		REM Arousal		BASELLNE Vs SWS		BASELINE Vs REM		SWS Vs REM	
Time block (mins)	Mean	SD	Mean	SD	Mean	SD	t	p	t	p	t	p
(a)												
0	4.17	1.95	7.42	1.68	7.75	1.42	-6.04	.000*	-8.25	.000*	-0.60	.28
6	4.17	2.13	6.58	2.07	6.25	2.05	-4.84	.0005*	-2.54	,014	0.38	.36
12	3.83	2.17	6.58	1.93	6.92	1.83	-4.21	.0005*	-5.68	.000*	-0.84	.21
18	4.00	2.34	5.75	2.49	6.75	1.91	-2.96	.0065*	-5.74	.000*	- 1.97	.037
24	4.33	2.31	5.58	2.54	6.58	2.07	-2.07	.0315	-4.55	.0005*	-1.86	.045
30	4.08	2.3 1	5.08	2.68	6.33	2.61	-1.59	.0695	-3.89	.0015*	- 1.99	,036

Note: degrees of Freedom * indicates significant at ,008 level

KSS Results

The data indicates that at 0, 6, 12 and 18 minutes, post SWS subjective sleepiness scores were significantly higher than the baseline subjective sleepiness scores obtained. By 24 minutes after SWS arousal, the results indicate that there was no significant difference between the subjective sleepiness ratings reported after SWS arousal compared with the baseline, although trends in the expected direction are evident.

The data indicate that immediately following REM arousal, subjective ratings of sleepiness were significantly higher than those reported during the baseline. At six minutes following REM arousal, there was no significant difference between ratings obtained compared with baseline ratings, although it was approaching significance. At 12 to 30 minutes following arousal from REM sleep, reported ratings of sleepiness were significantly higher than those reported at baseline. At 30 minutes subjects were still reporting higher ratings of sleepiness compared with baseline ratings.

Comparison of subjective sleepiness ratings following SWS and REM sleep indicated that there were no significant differences.

Clear Headed Ratings

Data Analysis

In order to determine any differences between subjective ratings of clear headedness six comparisons were made across the full 30 minutes following arousal using one tailed paired t-tests and the Bonferroni adjustment was applied from an alpha level of .05, resulting in a .008 significance level.

Table 3.
Means, (and standard deviations) t values and p values for clear headed ratings comparing baseline with post SWS arousal ratings and post REM sleep arousal ratings.

	BASELINE		SWS Arousal		REM Arousal		BASELINE VS SWS		BASELINE VS REM		SWS Vs REM	
Time block (mins)	**Mean**	SD	Mean	SD	Mean	SD	t	p	t	p	t	p
(a)												
0	2.17	0.94	3.5	0.91	3.67	0.99	-5.93	.000*	-7.71	.000*	-0.62	.28
6	2.08	0.90	3.17	1.03	3.33	0.99	-4.73	.0005*	-4.10	.001*	0.62	.28
12	2.00	1.04	2.92	0.10	3.00	1.13	-2.73	.01	-3.63	.002*	0.32	.38
18	2.00	1.04	2.75	1.06	3.08	1.08	-2.69	.0105	-4.17	.001*	**- 1.48**	.08
24	2.08	0.10	2.67	1.16	3.17	1.12	-2.03	.0335	-4.17	.001*	-2.57	.01
30	2.08	0.10	2.75	1.14	2.83	1.34	-2.60	.0125	-2.46	.016	-0.36	.36

Note: degrees of freedom=1 1, N=12 * indicates significance at ,008 level

Clearheadness Results

As shown in Table 3, following SWS arousal significant differences between the ratings of clear headedness at 0 and 6 minutes arousal were found compared to baseline ratings. At ratings between 12 to 30 minutes post arousal, no such significant differences were evident.

Significant differences between clear headed ratings following REM sleep arousal and baseline ratings at 0, 6, 12, 18 and 24 minutes post arousal were also found. That is, subjects rated themselves as being significantly less clear headed following REM sleep arousal compared with baseline for 24 minutes.

There were no significant differences between the clear headed ratings obtained after SWS arousal compared with those obtained following REM sleep arousal.

Correlations

Correlations were performed on the dependent variables (performance, subjective sleepiness and clear headedness) to detect any relationships. There were no significant correlations among the performance scores and their corresponding sleepiness and clear headed ratings. However the sleepiness ratings consistently correlated with their corresponding clear headed ratings (five of the six coefficients $\geq .63$, $p < .05$).

DISCUSSION

These results demonstrate that sleep inertia following arousal from SWS does effect decision making performance, with subjects performing at only 5 1% of their optimum performance within the first three minutes after waking. A decrement in decision making performance was found for the first 12 minutes immediately after S WS arousal compared with baseline performance.

Decrements in decision making performance following REM sleep arousal were less straightforward. There was a clear decision making decrement within the first three minutes after REM arousal, whereby subjects were only performing at

65% of their optimum performance capability. However, performance improved between 3-6 minutes, where the decrement was no longer significantly different to baseline performance. Surprisingly, the decrement in decision making performance was once again present and was significant at 9-12 minutes following REM arousal, where subjects were performing at 75% of their optimum performance.

Perhaps these findings suggests that following REM sleep arousal, subjects are able to arouse themselves for a brief period of time (i.e. 3-6 minutes post arousal) to improve performance, whereas subjects may be less able to do so after SWS arousal. Consistent with the performance improvement in the 3-6 minute interval is the finding that subjects' subjective sleepiness ratings improved markedly at the six minutes time point after REM arousal. Sleep inertia is said to be a period of great attentional lability with lapses (Tassi et al., 1992) and it has been argued that subjects can exert additional effort for brief periods of time to overcome performance deficits (Dinges & Kribbs, 199 1). A highly stimulating task will help foster the motivation needed for selected periods, but cannot guarantee that the impairment in performance produced by sleepiness will be completely overridden indefinitely. Horne (1988) proposes that, within some range of sleepiness, performance deficits can be overridden by the input of motivational or attentional resources. It is conceivable that subjects were able to temporarily arouse themselves more easily following REM sleep awakenings compared to SWS, since REM sleep is characterised by higher brain reactivity and excitability than S WS (Dujardin et al., 1989).

These findings, which demonstrate sleep inertia effects on decision making performance and subjective ratings, are consistent with the theoretical models previously mentioned that incorporate the postulated sleep inertia component. For instance, Folkard and Akerstedt's (1992) 'process W' of the three process model of the regulation of alertness and sleepiness is further supported. They also support the notion that sleep inertia is a period of confusion and decreased alertness, which consequently impairs the essential cognitive abilities of vigilance and alertness, necessary for sound and rational decision making (Janis & Mann 1979).

With regard to comparisons of performance and subjective ratings of SWS arousal compared to REM arousal, not one comparison at any time point achieved statistical significance at the conservative alpha level applied. Perusal of the results shows occasional trends at particular time points but no consistent pattern of differences emerges.

The present findings are similar to those of Koulack and who did not find significant differences between performance following REM and non-REM sleep arousal on trail making and vigilance tasks. The results also correspond with those obtained by Dinges et al., (1981), who found that waking from SWS compared with REM sleep in a nap study did not appear to differentially effect complex cognitive functioning as assessed by a descending subtraction task.

Perhaps this indicates that the severity of sleep inertia effects on performance may not simply be associated with the pre-awakening stage of sleep. For instance, it has been suggested that cognitive performance is'related to the total amount of SWS preceding awakening and other factors associated with sleep depth rather than being directly related to the sleep stage at awakening (Akerstedt et al., 1989; Dinges et al., 1981, 1985; Naitoh & Angus, 1989; Stampi, 1989). Consistent with this, the severity of nocturnal sleep inertia may be influenced by the circadian time of night effect whereby performance decrements can reach maximum levels at different times of the night for different tasks (Dinges, 1989). This study attempted to minimise confounding effects due to circadian factors by counterbalancing the order of SWS and REM awakenings across subjects. Perhaps this is why no significant SWS versus REM sleep inertia effects were found in the performance data.

On the subjective rating scales, subjects reported themselves as sleepier and less clearheaded, compared to baseline, for the majority of the 30 minute period after both SWS and REM awakening. Interestingly, for both sleepiness and clearheadedness ratings, the ratings remained significantly different to baseline for longer following REM sleep than SWS. In other words, subjective recovery of sleep inertia was more rapid following SWS than REM (although direct statistical comparisons between the two did not yield significant differences). This finding is difficult to reconcile with the previous literature that has found sleep inertia (measured using performance measures) to be more severe following SWS arousal than REM arousal. Again, (as in the above discussion of performance scores) it may be possible that the counterbalancing of the order of SWS versus REM sleep arousals across subjects in the present study has reduced the likelihood of greater sleep inertia effects arising from the SWS awakenings (that typically occur earlier in the night than REM awakenings).

Such counterbalancing is critical to avoid a systematic bias, especially if more than one awakening per night is used. Work in this area, like that of arousal thresholds, needs to systematically control for more potential confounding variables including time of night, length of prior sleep, amount of prior sleep stages and duration of prior wakefulness. Further understanding of the effects of such variables may resolve the current inconsistencies in the literature whereby some studies do show significant differences in sleep inertia as a result of sleep stage of awakening (Bonnet, 1983; Dinges et al., 1985 Mullington & Broughton, 1994; Stones, 1977).

Correlational analyses suggest that there were no significant relationships between any of the decision making scores and the corresponding sleepiness ratings, or between the decision making scores and the corresponding clear headed ratings. Nonetheless, in the present study most of the subjective sleepiness ratings did significantly correlate with the clear headed ratings. As the clear headed scale was exploratory, this latter finding raises the question of whether clearheadedness is a part of sleepiness or not, that is, whether the two variables have discriminant validity. It is too early to be certain from this study. Further studies manipulating sleepiness and potentially confusional states are required to determine whether these two variables are independent constructs, the same or confounded constructs.

This study did not investigate the effects of noise on sleep inertia as the alarm that aroused subjects was immediately turned off. Tassi et al., (1992) found that an intense continuous noise produced a total abolishment of sleep inertia after an early nap, yet noise had no effect on a later nap. This demonstrates that the effects of noise on sleep inertia requires further investigation. Furthermore, the present study required the subject to stay in bed, with only a very dim light on. It is acknowledged that activity and perhaps bright light, may also abolish or decrease sleep inertia, and this requires further research.

Although much remains to be determined about the variables influencing decision making performance upon abrupt awakening, this study is the first step in documenting the effects of sleep inertia on decision making performance; an area of research with important implications for understanding psychological functioning in emergency situations.

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