FINAL REPORT

IMPROVING ADAPTATION TO NIGHT SHIFT

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Abstract

Poor quality sleep and chronic sleep deprivation are two of the central health and safety issues facing shift workers. These difficulties are the direct consequence of the inability of the human body to adapt instantly to shifts in the timing of work and sleep relative to the timing of the biological clock. Improving adaptation to shift work, and night shift in particular, requires shift designers to consider the underlying physiology of the worker. This research project was funded to evaluate novel techniques for improving adaptation to night shift based on a sound understanding of the biological factors that control the adaptation process.

In the first study, we evaluated the use of bright artificial light to **shift** the biological clock controlling the quality and duration of sleep and wakefulness. In the second study, we evaluated the use of a naturally ocurring hormone, melatonin to **disconnect** the biological clock and reduce its control on sleep. In addition, we compared the two techniques to see which was the most beneficial and under which circumstances we should employ either or both strategies.

The results of the first study clearly indicated that bright light can be used to shift the timing of the biological clock and to improve day sleep during a three day transition to night work. As a consequence, night-time alertness was increased and subjects reported significant improvements in adaptation relative to the control group. In the second study, melatonin proved equally effective in improving daytime sleep but produced only moderate improvements in night time alertness. Overall, the results indicate that bright light is the more effective technique but that practical considerations suggest it would be most appropriate for use with slowly rotating shift cycles. In contrast, the melatonin treatment, while less effective in improving night time alertness, is ideally suited for use in rapidly rotating shift cycles.

In conclusion, these results provide the first clear evidence that adaptation to shift work can be manipulated in a practical and effective manner. In addition, the results indicate that we can employ a variety of alternate strategies to permit the optimum design of shift rosters. On the basis of these results, it would now be appropriate to transfer the results of our lab-based studies into the workplace and to determine their effectiveness in real-world settings over extended periods.

Acknowledgement

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Executive Summary

Background

Poor quality sleep and chronic sleep deprivation are two of the central health and safety issues facing shift workers. Impaired sleep quality is accompanied by increased sleepiness during the waking period, unavoidable napping and reduced mental alertness. These effects frequently lead to impaired decision making and, not surprisingly, a significantly more dangerous workplace. The direct consequences of chronic sleep deprivation have long been considered one of the main reasons why industries with significant numbers of shiftworkers report a significantly higher incidence of work-related accidents, increased medical and compensation costs and lower levels of psychological well-being.

Despite our extensive understanding of the social costs associated with shiftwork, current work practices in the minimg and quarrying industry rarely consider the biological factors underlying our inability to adapt to night work. As a consequence, there is an urgent need to develop effective strategies that minimise the health and safety risks associated with shiftwork.

The underlying biological mechanisms that determine the quality and duration of sleep, and its effect on subsequent waking function in shiftworkers, are well understood. Essentially, the body is influenced by an internal 'biological clock' that times a variety of body systems. The timing of sleep relative to this body clock determines its efficiency and restorative capacity (i.e. how refreshed we feel when we wake up and how well we perform while we are awake). During night shift, workers shift the timing of their sleep relative to their 'circadian' or body clock sleep. In effect, they are sleeping at the wrong circadian time.

This shift in the timing of sleep, relative to the circadian system, leads to shorter, more fragmented sleep. In addition, the inertia of the circadian system prevents individuals adapting to their changing shift cycle instantly. Thus, in many shiftworkers, we observe a continual malaise related to poor sleep and reduced alertness: a form of permanent industrial 'jet-lag'. If we could increase the rate at which the circadian system adapts to these phase shifts or reduce the extent to which our biological clock regulates sleep quality, we could reduce many of the negative consequences of shiftwork and improve health and safety in shiftworkers.

Summary of methodology

Recent research has indicated that it is possible to accelerate the rate of circadian adaptation through the use of appropriately timed bright light. By shifting the biological clock more rapidly, it has been thought possible to restore normal sleep by the second sleep period following transition to night shift. This acceleration of the adaptation process has been hypothesised to reduce sleep disruption and improve adaptation.

For workers on slowly rotating shifts, accelerating the rate of adaptation restricts the amount of sleep disruption to one day. Given that slowly rotating shifts have four or more night shifts this effectively reduces the degree of sleep disruption to less than a quarter of the day sleep periods. This compares favourably with normal control workers who report that 75-80% of day sleep periods are excessively disrupted.

In rapidly rotating shifts, where the night shift is typically between 1 and 3 nights, using bright light to rapidly shift the circadian system would be beneficial but would still result in 50% of day sleep periods being disrupted. In this type of shift cycle, it is generally considered best to minimise the degree of circadian adaptation and 'tough it out' for the short night shift period.

The best approach in this situation is to try and stabilise the biological clock and keep it in the normal day shift position. To understand how we approach this it is important to understand how the biological clock interrupts sleep. Normally, the biological clock is set to increase metabolic rate during the day while we are awake and reduce metabolic activity at night when we try to sleep. By analogy, the biological clock turns up the thermostat, i.e. body temperature during the day and then lowers it at night. In shift workers, day sleep is interrupted because the thermostat has not adjusted to the new time. Body temperature is still rising during the day when sleep is attempted.

In rapidly rotating shift cycles, we can trick the sleep system into thinking it is 'night time' by lowering core body temperature. Lower core temperature enables the individual to sleep better without having to shift their biological clock. The way we do this is to use the same hormone the biological clock uses to reset the body's thermostat. This hormone is called melatonin and is usually produced in the pineal gland. Luckily, it can be synthesised artificially and taken orally.

By giving melatonin during the day, we lower core body temperature and allow people to sleep at the wrong point in their biological rhythm. This strategy is quite different to the bright light treatment. With bright light we are **shifting** the hands of the clock to the right time for sleep. With daytme melatonin administration we are **disconnecting** the hands of the clock To evaluate the relative merit of these two strategies we compared them on similar shift transitions. Thus, in the second study we have compared the effectiveness of melatonin and bright light to improve sleep and thereby improve on-the-job alertness.

Results

Study 1

This study examined the extent to which appropriately timed exposure to bright light would accelerate the circadian re-adjustment of physiological parameters thought to contribute to impaired performance in shift workers. A control (n=7) and treatment group (n=6) underwent a three-day transition to simulated night work. The treatment group received a single four-hour pulse of bright light (6000 lux) between 2400h and 0400h on the first night shift and dim light (<200 lux) for the remainder of the study. The control group received dim light throughout. By the third night shift the phase position of the core body temperature rhythm for the treatment group had delayed by 5-6 hours whereas the control group had delayed by only 2-3 hours. When compared to the control group, the greater delay in core temperature rhythm for the treatment group was associated with significantly higher alertness across the night shift and improved sleep quality during the day. By the third day sleep, mean sleep efficiency in the treatment group was not significantly different from normal night sleep. Similarly, on-shift alertness was improved relative to the control group. The treatment group did not show the typical decline in alertness observed in the control group between 0300h and 0700h. These data indicate that a single four hour pulse of bright light between midnight and 4 a.m. is effective in ameliorating the sleep and alertness problems associated with transition to night shift.

Study 2

In this study we compared adaptation to night shift in three groups of subjects. The first treatment group received timed exposure to bright light (4-7,000 lux between 2400 and 0400 on each of three night shifts). The second treatment group received exogenous melatonin by capsule (2mg at 0800h then 1mg at 1100 and 1400h). The placebo control groups received either dim red light at less than 50 lux or placebo (sucrose) in identical capsules at the same time.

Results indicated that all groups shifted significantly from baseline. Using the dim light melatonin onset as a circadian marker, the bright light group shifted the furthest while there was no significant difference between the melatonin and placebo groups. Sleep quality as determined by wrist actigraphy was most improved in the light treatment group, although the melatonin group also showed significant improvements. Cognitive psychomotor performance was most improved in the light treatment group and the melatonin group again showed little difference from the control group. While melatonin was unable to increase the amount of the phase shift following transition to night shift, it is likely that the intermediate levels of improvement in sleep reflect the hypothermic effects of melatonin. By lowering core temperature across the sleep period, sleep may be enhanced. This improvement in sleep quality did not produce concomitant improvements in shift performance for the melatonin group. This suggests that the enhanced performance in the light treatment group may reflect more direct 'energising' effects.

On the basis of these results, bright light is clearly superior in its ability to phase shift the circadian system and thereby improve sleep and performance. However, melatonin may permit shiftworkers to 'over-ride' the circadian system for short periods and avoid the potential toxicity due to over zealous manipulations of the circadian pacemaker. In rapidly rotating shift schedules, melatonin may be preferable since it would not require workers to reverse the large phase shift induced by light.

Conclusion

Taken together, these studies indicate that adaptation to night shift can be significantly improved through the use of appropriately timed exposure to bright light or melatonin administration. Bright light appears to be the most appropriate treatment strategy for improving adaptation when workers are required to work on slowly rotating shifts. In this situation, the biological clock can be shifted in a relatively short time compared with the duration of each leg of the specific shift system. Workers can adapt to the new cycle relatively quickly and can be re-adapted quickly at the end of the cycle.

On the other hand, melatonin adaministration appears to be more appropriate for those working rapidly rotating shifts. In these individuals, melatonin improves daytime sleep by reducing core temperature and stabilising the circadian system. In effect, disconnecting the biological clock. As a consequence, the circadian system's control of sleep quality and subsequent alertness is attenuated and the principal negative effect of night work, i.e. sleep disruption, is eliminated. When we compare the relative effectiveness with bright light treatment, melatonin produces only intermediate improvements in on-shift alertness. This is likely to reflect the fact that the circadian clock , in addition to controlling the quality and duration of sleep, also controls daily variations in alertness and cognitive psychomotor performance. In future studies, it would be important to also disconnect the 'clocks' drive on nocturnal alertness by suppressing endogenous nocturnal melatonin production.

An important practical consequence of these findings is that the length of rotating shift cycles should be polarised according to the nature of the work environment. In this project, we used a three day transition because it was an intermediate length that enabled us to compare each of the strategies for both the short and long shift cycles used in the mining and quarrying industry. On the basis of the results reported here, industry could significantly improve overall adaptation by eliminating shift cycles of intermediate length. It would be preferable to require shift rotations to be either (a) longer than 5 days, or (b) shorter than 3 days. Adaptation could then be optimised by employing the most appropriate intervention strategy. That is, shifting, or disconnecting, the biological clock.

These results also carry important consequences for our undestanding of the relationship between workplace and roster design. For example, in shift settings where workers are sedentary and confined to a small indoor space, bright light interventions could be implemented relatively easily. In this case, shift cycles should be longer than 4 days. On the other hand, workplaces where it is impractical or too expensive to generate sufficient light intensity to improve adaptation, would be most amenable to short cycle rotations and daytime administration of melatonin.

In summary, these results provide the first clear evidence that adaptation to shift work can be manipulated in a practical and effective manner. In addition, the results indicate that we can employ a variety of alternate strategies to permit the optimum design of shift rosters. On the basis of these results, it would now be appropriate to transfer the results of our lab-based studies into the workplace to determine their effectiveness. In the current study, we have examined the improvement in adaptation for a single night shift cycle. It will be important to determine whether improvements observed in this study continue to be observed over several shift cycle. To determine the answer to these questions, it is important to transfer the research into an applied setting.

This is now technically feasible since the ambulatory sleep and performance measures developed in the second study would appear both valid and highly reliable. As a consequence, they will permit inexpensive, long-term monitoring in field studies. Similarly, the circadian, actigraphic and performance measures developed in these studies show considerable promise for identifying individuals differentially affected by shiftwork. This may be of benefit in identifying shiftworkers who are at risk and permit approporiate interventions to improve individuals safety.

DETAILS OF CONSULTATION PROCESS

This project was laboratory-based. As a consequence, the consultative process occurred primarily at the start of the project. Prior to funding, the individuals and organisations listed on the next page were contacted to determine

(a) the extent of the problem in the mining and quarrying industry

(b) the relevance of the project,

(c) the potential benefits to the industry,

(d) the design of the experimental protocol. This was critical to ensure that the specific nightshift transition studied (i.e. time and duration of the shift) was representative of the type of shift schedules commonly employed in the industry. On the basis of these discussions, the experimental protocol employed a three-day transition to night shift with an eight hour shift duration.

Following completion of the study, the second phase of the consultative process should begin through dissemination of the results to the relevant industry participants. I would suggest that copies of the executive summary be made available to the key industry players listed below. Furthermore, I believe it is now appropriate to convene an industry-wide forum to communicate the results of this study with the following aims

(a) clearly define the occupational health and safety risks associated with shiftwork at work *and* at home,

(b) introduce and evaluate the field-based techniques for hazard identification we have developed in these studies,

(c) use the results of these studies to promote workplace initiatives that minimise the occupational health and safety risks associated with poorly designed shift schedules,

(d) develop and evaluate effective educational initiatives to promote the capacity of employers and employees to identify accurately those hazards that result from shiftwork related issues,

(e) design and evaluate effective educational programs to help workers and employers minimise the negative medical and psychosocial impact of shiftwork

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