BROAD SPECTRUM LIGHT AND NIGHTTIME COGNITIVE PERFORMANCE: EFFECTS OF INTENSITY, DISTANCE, AND DURATION

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ABSTRACT

The main purpose of the present investigation was to find out if changes in intensity of a bright light source differentially affected nighttime performance when the intensity was varied at the source compared to moving participants in relation to the source. Previous research has not studied distance from source specifically as an independent variable. The present study also attempted to find out if duration of light exposure would influence performance tasks as previous findings suggest (McIntyre et al., 1989; Lewy et al., 1980). Duration of exposure had not been systematically examined as an independent variable until Baker (1999) studied the effects of both 15-min and 60-min durations on mental performance. Light levels of baseline (>100-lux, normal room lighting), 1,000, and 2,000 lux were paired with 2 different duration conditions (15-min prior and 60-min continuous), and two different distance conditions (Fixed and Moved distance). Twenty volunteers completed tests of mathematical reasoning, logical reasoning, vigilance, memory recall, and memory recognition between 2400 hrs and 0100 hrs once a week for six consecutive weeks. The results showed that the method of varying light intensity does seem to matter if only for the 2,000-lux intensity and, overall, the 15-min duration condition resulted in better performance than the 60-min duration condition. The present study produced inconclusive results in regard to the duration of exposure and in regard to the method of varying light intensity. However, it is possible to conclude that the method of varying light intensity probably does impact performance. Furthermore, the present study raises two serious methodological concerns in regards to the speed-accuracy tradeoff problem and in regard to the standardisation of task type.

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Finally, to those friends, family, and flatmates that tolerated my mood swings, foul temper, and generally poor behavior over the 17 weeks of data collection in which time I had very little night time sleep. I can now empathise with those who work at night and understand the effects that working at night can have on people. My own experience while conducting this study has made me believe, more than ever, that this type of research is important.

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INTRODUCTION

Background

The expression "as sure as the night follows day" reflects the stability of certain cycles in our environment. The earth spins on its axis approximately once every 24 hrs and submits organisms to a highly predictable daily pattern of light and temperature. It is not surprising, therefore, to discover that most organisms follow a 24-hr schedule (Coleman, 1986).

Almost all animals go through alternate periods of activity and inactivity. These are generated from either within the body (endogenous) or from factors in the surrounding environment (exogenous). Cyclical activities are basic characteristics of animal life. A cyclic period can be defined in terms of the time it takes to complete one full cycle of activity. A cycle that lasts one day is said to have a period that is circadian (circa = approximately; die = day).

Endogenous rhythms help an organism to predict changes in the external environment. This means that rhythms must persist independently of changes in the surrounding environment when an organism is cut off from them. For example, when an organism is isolated from the light/dark cycle by being placed in constant light or constant darkness, all endogenous rhythms continue to cycle, although the period usually exceeds that of the 24-hr period by approximately 1 hr. When this occurs, the rhythmic activity is said to be free running.

Twenty-four-hr rhythms in plants and animals have been recognised from ancient times. The marches of Alexander the Great document the daily movements of leaves and flower petals. Greek myths describe these movements as a continual expression of love for the sun god, Helios. The rhythm implied that the "sleep movements" of these plants, which we now call heliotropes, were a passive response to the disappearance and reappearance of sunlight. This assumption remained untested until 1729 when Jean Jacques d'Ortous de Mairan moved a heliotrope plant away from the sunlight and the plant continued to unfurl its leaves in the day and close them at night. This demonstrated the persistence of circadian rhythms in the absence of environmental time cues (de Marian, 1729; cited in Moore-Ede, Sulzman, & Fuller, 1982).

Realising that he could not pursue his research to the extent he wished, de Mairan extended invitations to botanists to carry on the research process. In 1759, Duhamel Du Monceau repeated de Mairan's experiments and reported that the rhythm of leaf movements was not caused by variations in environmental temperature (Du Monceau, 1759; cited in Moore-Ede et al., 1982).

Finally, in 1832, Augustin de Candolle discovered that the daily leaf movements not only persisted in constant darkness but that the leaves opened an hour or two earlier each day, displaying a rhythmicity of 22-23 hrs. This was the first demonstration that circadian clocks "free run" when they are no longer synchronized to the light/dark cycle (de Candolle, 1832; cited in Moore-Ede et al.,1982).

An organism's internal clock, known as the circadian timing system, has developed during the course of evolution. It is unknown why, but perhaps it allows organisms to predict change in their environment, increasing the chance of survival. The circadian rhythm is an output of a system whose main function is to measure time, and the cellular machinery is called the biological clock. Endogenous clocks impact on many bodily functions including neurotransmitters, secretion of hormones, sleepiness, and body temperature.

Underlying Theories

The Physiology Underlying Circadian Rhythms

The first direct search for the circadian pacemaker in mammals did not take place until the 1960s. At that time Curt Richter undertook a series of tests (Richter 1965, 1967) where he placed lesions in various locations throughout the nervous system of rodents. He found that these disrupted circadian rhythmicity only in the area of the anterior hypothalamus (see Figure 1).

Using blinded rats and their free running activity rhythms as his circadian system marker, he subjected his animals to all kinds of metabolic and neurological interference. He found that procedures such as removal of the adrenals, gonads, pituitary, thyroid, and pinealor pancreas all failed to disrupt the rats "free running" rhythms, as did electroshock therapy, induced convulsions, prolonged anesthesia, and alcoholic stupor.

In 1972, two independent groups identified a small, bilateral pair of nuclei in the anterior hypothalamus, the suprachiasmatic nuclei (SCN, see Figure 1), as a potential circadian pacemaker (Moore & Eichler, 1972; Stephan & Zucker, 1972). Lesions that destroyed the SCN were found to eliminate circadian rhythmicity in many physiological and behavioral variables. Most research on circadian rhythms supports the hypothesis that the SCN is the main circadian pacemaker. The SCN is located in the anterior hypothalamus, lateral to the third ventricle and directly above the optic chiasm. It is now known that circadian rhythms are entrained (adjusted) by environmental cues or *zeitgebers* (time-givers). The most important cue to the SCN is light.

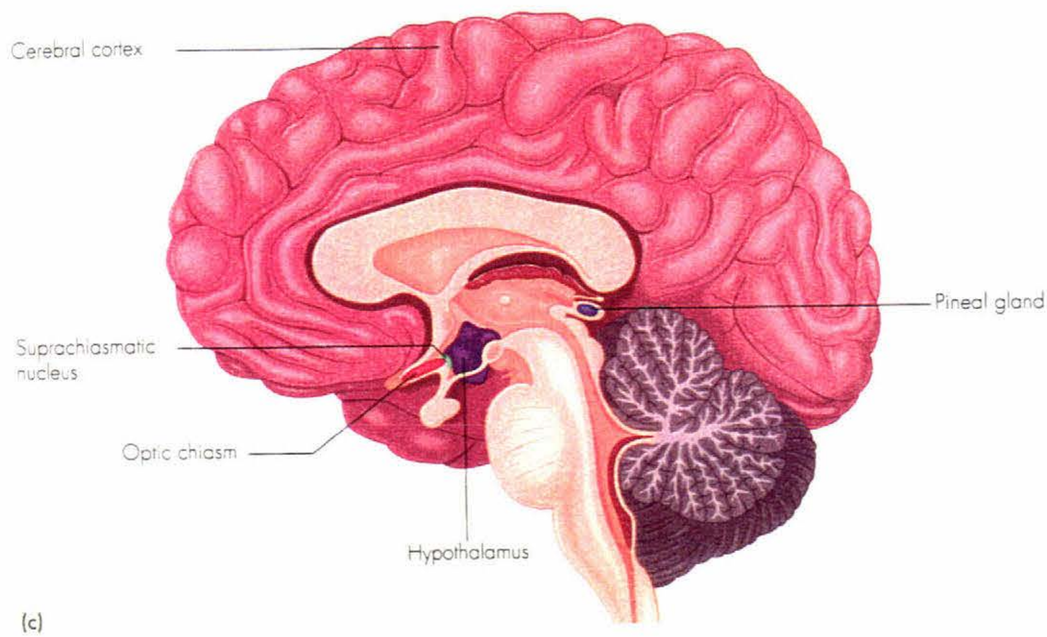

Figure 1: Midsagittal section of the human brain showing the pineal gland, pituitary gland, suprachiasmatic nucleus, and hypothalamus. Source: Kalat, 1998, p. 247.

The SCN contains approximately 10,000 neurons whose efferent projections terminate in the paraventricular nucleus (Zucker, Lee, & Dark, 1991). Afferent connections relay photic information from the retina to the SCN via the retinohypothalamic tract (RHT). Klein and Moore (1979) found that sectioning of all visual pathways in animals beyond the RHT does not affect entrainment. Sectioning of the RHT itself abolishes entrainment, supporting the theory that the primary circadian pacemaker involves the SCN.

Although there is no conclusive evidence to support the hypothesis that the SCN is the main circadian pacemaker, Moore (1995) reports that four lines of evidence now strongly support the idea that the SCN is the primary pacemaker. Firstly, afferent connections relay information about light to the SCN via the RHT. Secondly, removal of the SCN eliminates most circadian functions. Thirdly, circadian function can be maintained in the isolated SCN, and fourth, transplantation of foetal SCN tissue into the third ventricle of SCN-lesioned animals restores rhythmicity.

Although removal of the SCN eliminates most circadian functions, it is now thought that there are two groups of rhythms driven by different pacemakers. One pacemaker known as the sleep/wake cycle rhythm drives rhythms such as skin temperature, plasma growth hormone, urine calcium excretion and slow-wave sleep. Another pacemaker known as the body temperature rhythm drives REM sleep, plasma cortisol, urine potassium excretion, and body temperature (Moore-Ede et al., 1982).

Circadian Rhythms

Studies that isolate individuals from day/night influences show daily fluctuations in some human functions (Czeisler, Weitzman, Moore-Ede, Zimmerman, & Knauer, 1980). Basic body functions such as cardiovascular and respiratory functions, blood pressure, heart rate, responsiveness to hormones, and blood flow and volume all show circadian variations and generally desynchronise into the two above-mentioned groups.

Some behaviors, such as the sleep/wake cycle and cognitive performance also show variations across the day. Circadian rhythms allow us to prepare for regular fluctuations in our environment. To take advantage of this, it is necessary that they be entrained to the external world.

In the absence of time cues, rhythms normally deviate from 24 hrs in humans; most individuals cycle about every 25 hrs (Arendt, 1995). Circadian rhythms are developed by way of entrainment, or daily resetting. The entrainment process is moderated by endogenous and exogenous factors (zeitgebers). Endogenous rhythms are those rhythms in the body that trigger activity cycles like body temperature and heart rate. They can be entrained to exogenous factors such as light, the sleep/wake cycle, clocks, and social activities such as work, school, meals, exercise, recreation, and interpersonal interaction.

The range of entrainment appears to depend on the strength of the zeitgeber. From his early studies, using an artificial light/dark cycle and gongs that signaled time for various tasks, Wever (1979) found that people easily became entrained to social cues. Wever (1989) has also shown that a sleep/wake schedule is an effective zeitgeber in constant darkness though it has been pointed out that many blind people have free-running or abnormally phased circadian rhythms (Eastman, 1990).

Despite the discoveries that a sleep/wake schedule and social cues can act as zeitgebers, it is generally believed that the light/dark cycle is the most important zeitgeber for mammals. Lewy and Sack (1987) proposed that light has two effects on the human circadian system: a direct zeitgeber effect and a social cue effect. The RHT and the SCN, which synchronize a variety of rhythms, including body temperature, melatonin secretion, and the sleep/wake cycle, mediate the direct zeitgeber effect. Social zeitgebers acting via the sleep/wake cycle may entrain rhythms by gating exposure of the SCN to light as opening and closing the eyes mediates retinal light exposure.

It has been shown that exposing mice and hamsters to high intensity light during the "subjective night" can shift their circadian clocks. Light of suitable intensity and spectral composition is able to suppress melatonin production at night. Hence, light both entrains circadian rhythms and suppresses melatonin (Lewy, Wehr, Goodwin, Newsom, & Markey, 1980). It is now believed that the suppression of melatonin is what changes nighttime behavior in humans.

Melatonin and the Pineal Gland

Melatonin levels in blood plasma act as a circadian rhythm's marker and reflects the length of night in animals. In some lower vertebrates, the pineal gland (see Figure 1, p. 4) has a major role in organising circadian rhythms. In some species of birds and lizards, the pineal gland serves as a circadian clock, actually generating the day/night rhythms, though in mammals, removal of the pineal gland does not disrupt circadian rhythms. Arendt (1995) states that, for mammals, the central rhythm-generating system resides in the SCN and production of melatonin is a "driven" rhythm. The reason is that the SCN and the pineal gland are connected in the mammalian brain.

As a result of light/dark information received by the SCN, the pineal gland secretes melatonin during the night. Nocturnal melatonin levels are 30-70 times higher than diurnal levels (Minors & Waterhouse, 1981). In animals with a SCN, circadian rhythms of melatonin release are regulated via neural signals from the SCN. If the SCN is destroyed, pineal melatonin secretion is abolished. Furthermore, melatonin secretion is entrained to the 24-hr light/dark cycle via the retina and the RHT to the SCN, and is believed to be circadian, as it has been found to persist in constant darkness (McIntyre, Norman, Burrows, & Armstrong, 1989). Concentrations of melatonin receptors in the SCN suggest there may be a feedback loop between the pineal gland and the SCN.

Dr. Alfred Lewy and the Discovery of Bright Light Effects

In contrast to the situation in all other mammals tested, early studies on human melatonin secretion indicated insensitivity to light. Recently, however, it has been shown that light does suppress melatonin secretion in humans but only at relatively high intensities.

Upon returning to the USA from a trip to Australia, nine time zones away, Dr. Alfred Lewy drew a sample of his own blood for a newly developed melatonin assay (Lewy & Markey, 1978). He was expecting to find large quantities of melatonin, since melatonin secretion peaks at night and the sample was drawn at the time of the Australian night. When very low melatonin levels were detected, he was quite surprised and wondered whether the sunlight on arrival home suppressed his melatonin secretion. The suppression of nocturnal melatonin secretion by light was well known in other animals but had never been demonstrated in humans. Subsequent systematic experimentation confirmed that humans were like other animals after all. Light suppressed nocturnal melatonin secretion, but only at high levels, greater than those produced by ordinary indoor lighting.

The pivotal study by Lewy et al. (1980) triggered the modern field of bright light research, and the idea that artificial bright light might be used to shift human circadian rhythms. One of the first researchers to test the idea was Wever (1985). He repeated many of his basic experiments on light and human circadian rhythms because in previous work the light intensity was well below threshold for melatonin suppression. His new research showed bright light to be a more powerful zeitgeber than any other tested (Wever, Polasek, & Wildgruber, 1983; Wever, 1986; 1989).

After some years of research in this area, McIntyre et al. (1989) reported that 1 hr of light at 1,000-lux[1] intensity was sufficient to suppress melatonin to near daytime levels. Intensities as low as 350 lux were shown to significantly suppress nocturnal melatonin secretion. This substantiated Lewy et al.'s. (1980) claims that high intensity lighting does indeed suppress melatonin.

Lewy et al. (1980) also claimed that there was a dose-response relationship between light and melatonin, in that the more intense the light the greater the suppression. This finding was supported by McIntyre et al. (1989) who reported that

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[1] Illuminance of a surface is defined as the luminous flux reaching it perpendicularly per unit area. The metric unit is the lumen m^{-2}, or lux (Tennent, 1971)..

maximum suppression of melatonin following 1 hr of light at midnight was 71%, 67%, 44%, 38%, and 16% with intensities of 3,000, 1,000, 500, 350, and 200 lux, respectively.

Further research has discovered that the time at which the light is applied is of some consequence. This concept, called the "phase response curve" (PRC), graphs how much a particular stimulus phase shifts a circadian rhythm. A typical PRC to light is generated from animals free running in constant darkness or dim light (Eastman, 1991). A pulse of light can be applied and the phase shift measured. The same pulse of light has different effects depending on when it is applied within the circadian cycle. Pulses in the middle of the "subjective night" (wake time for nocturnal animals and sleep time for diurnal animals) have the greatest effects whereas pulses in the middle of the "subjective day" have little or no effect. Pulses at the beginning of the "subjective night" delay rhythms (make the rhythms shift to a later time) while those applied at he end of the "subjective night" advance them (make the rhythms shift to an earlier time).

Wanting to know whether entrainment to a 26-hr zeitgeber was possible in the field, Eastman (1991) subjected participants to a 2-hr pulse of light (2,000-4,000 lux) each night at bedtime (designed to hit the delay portion of the PRC). Seventy-five percent of participants became entrained to the 26-hr cycle even when 24-hr zeitgebers provided conflicting messages. Since the average "free running" period for humans is about 25 hrs, this meant a phase delay of 1 hr per day. In summary, then, bright light is able to suppress melatonin secretion in humans in a dose-dependent manner. Bright light can also advance or delay human circadian rhythms depending on when it is applied within the circadian cycle.

Seasonal Affective Disorder and Bright Light Therapy

Despite the role light plays in the body's functioning, many people in modern society are deprived of natural sunlight. Most waking hours are spent indoors, under artificial light of low intensity. It is thought that many people do not get enough light to sustain daily rhythms.

It seems safe to assume that the body would have difficulty in sustaining daily rhythms in the absence of sufficient light. Without sufficient environmental light, the sleep/wake cycle and other biological rhythms may become desynchronised. It has been suggested that a number of illnesses which result from hormonal imbalances - sleep, appetite, mood, and reproductive disorders - could be linked to a disruption of circadian rhythms and ultimately to a lack of sunlight (Wehr & Goodwin, 1983).

Seasonal Affective Disorder (SAD) is an example of disturbed sleep patterns, appetite and weight disorders, and depression. All of these symptoms manifest in a yearly and daily cycle: they peak at the height of winter and are worst in the evening. Giving SAD sufferers artificial daylight has proved successful in correcting these disorders, which suggests SAD is associated with a lack of sufficient light.

Dr Alfred Lewy pioneered the use of bright light for the treatment of SAD. His earlier work (Lewy et al., 1980) suggested that bright light could be used to suppress the secretion of nocturnal melatonin in humans. He reasoned that SAD may have something to do with too much melatonin and that light may alter mood and other behavior. Two lines of reasoning bought him to this conclusion. First, melatonin is important in regulating seasonal rhythms in animals. Second, the nerve path involved in the suppression of melatonin secretion by light passes through parts of the brain important in regulating many of the physical functions that are disturbed in depression, such as eating, sleeping, weight control, and sex drive. The suppression of melatonin required much brighter light than ordinary indoor lighting. Lewy et al. concluded that bright light might also be necessary in order for the brain to perform other mood-related functions.

Lewy, Kern, Rosenthal, and Wehr (1982) began to treat one SAD patient with light therapy. The experiment involved putting the patient under bright light for 3 hrs morning and night, effectively extending the winter day. After 3 days the patient reported a dramatic improvement in mood. More studies followed which substantiated this earlier finding (for an in-depth discussion see Rosenthal, 1993).

Questions arose as to why bright light could be used effectively to treat SAD patients. It was initially thought that light worked by suppressing abnormally high levels of melatonin in SAD sufferers, thus alleviating the hormonal imbalances it caused. This theory was substantiated by a study that showed that if melatonin was given to patients during light therapy their symptoms were not alleviated. To the contrary, if SAD were just a case of excess melatonin in the system, drugs that prevent melatonin secretion could resolve this. Studies of Atenolol, a drug that has been shown to suppress the secretion of melatonin, show that this is not the case (Rosenthal et al., 1988).

Researchers began to look at the possibility that SAD patients suffer a disruption to their biological rhythms. SAD patients were monitored over 24 hrs to observe the rise and fall of melatonin. Peaks and troughs occurred several hours earlier than normal (Lewy, Sack, Singer, & White, 1987b). This suggests that the biological clocks of SAD sufferers may be delayed.

Noting that shiftworkers suffer mild depression, fatigue, lapses in alertness, and sleep difficulties, researchers were led to believe that the same treatment could be used on shiftworkers who are also thought to experience delayed circadian rhythms.

Circadian Rhythms, the Sleep/Wake Cycle, and Shiftworkers

What does the research into SAD and bright light have to do with shiftwork? Humans are subject to these rhythms to the same extent as other animals. Humans have a diurnal orientation. Working at night runs contrary to biological programming. In terms of night shift this means sleeping during the day (when the worker is supposed to be active) and working at night (when the worker is supposed to be at rest). When night shift is imposed on the worker, the circadian rhythm must move to adjust to a new cycle. The human body takes about a week to adjust and most rhythms are internally desynchronised during that time. It is now believed that the body may never fully adjust (Bougrine, Mollard, Ignazi, & Coblentz, 1995). This finding has implications for both the worker and the organisation.

Circadian desychronisation, inappropriately timed activity, and sleep loss may significantly affect performance on certain tasks. Research into the effects of fatigue and sleep loss has generally concluded that they have a negative effect on performance of most cognitive or mental tasks (Reid, Roberts, & Dawson, 1997). Due to circadian desychronisation and the sleep loss of workers, organisations may not maintain maximum productivity during the night hours.

Opportunity cost due to lost productivity is only one of the costs that organisations may incur. Other costs to the organisation include increased rates of absenteeism, psychological and social effects, increased staff turnover and therefore training costs, and the cost of increased numbers of accidents. Accident costs can include compensation, medical expenses, lawyers fees, substantial work and output delays, training new employees, cost of selection procedures, clean up costs, and shut-down/start-up costs.

Fortunately, organisations will experience only monetary and opportunity costs. Consequences for the worker appear to be more severe and have been catagorised under two headings. Firstly, sleep disturbances, where the quality and duration of sleep are decreased resulting in workers being unable to sleep in the day and unable to perform at night, and secondly, psychological disharmony, resulting in malaise, fatigue, and health and social problems.

Reid et al. (1997) report that 60%-70% of workers on rotating shifts complain of insufficient sleep and chronic fatigue. Combined, these two conditions lead to an accumulation of sleep debt resulting in increased tiredness, reduced alertness on the job, and greater risk of accidents.

Decreased levels of psychological well-being can result in higher rates of depersonalisation, exhaustion, and tedium, and lower rates of job satisfaction, and less satisfaction with personal and social life (Bussing, 1996). Social disturbances caused by shiftwork prevent the worker fulfilling family, social, sexual, and parenting roles, affecting variables such as mood and motivation. Health problems are also associated with shiftwork. Cardiovascular disease (Costa, Ghirlanda, Minors, & Waterhouse, 1993), drug taking, smoking (Barak et al., 1996), and alcohol intake (Gordon, Cleary, Parker, & Czeisler, 1986) are prevalent in nightworkers. All of these factors may have an indirect effect on performance of the job.

The Sleep/Wake Cycle and Performance

In field studies of task performance, most measurement methods are based on the idea that the influence of a disturbed sleep/wake pattern, especially during night work, will be reflected in a decrease in performance. From reviews of relevant literature, it can be concluded that most studies do indeed indicate that performance is worse at night compared to the daytime. Early research showed that performance variation parallels body temperature variations, but it is now known that performance does not decrease on all tasks during a 24-hr cycle (Folkard, Totterdell, Minors, & Waterhouse, 1993).

In general, most aspects of performance improve over the day, peaking between 1600 hrs and 1800 hrs and getting lower during the night dipping between 0400 hrs and 0600 hrs. Most aspects of performance are lower at night due to circadian influence and sleep deprivation. Performance is also moderated by factors such as fatigue and motivation. Sleep loss has a more direct influence on performance resulting in slower reaction time, delayed responses, failing to respond at the correct time, false responding, slow thinking, and diminished memory (Reid et al., 1997).

Variance in performance on different mental tasks depends on the nature of the mental processes involved. Sensorimotor and perception tasks mirror body temperature, dipping just after lunch and again between 0400 hrs and 0600 hrs. Short-term memory tasks peak in the morning and decrease steadily during the day. De Vries-Griver and Meijman (1987) state that performance depends on the memory load of the task. Tasks with low memory load, or immediate transfer of information, improve over the day while those with high memory load and storage of information in working memory get progressively worse. Other factors that may also cause performance decrements are task duration, new tasks, and external pace-setting (Johnson & Naitoh, 1974).

Folkard and Totterdell (1991) report that performance rhythms differ considerably with respect to the magnitude of endogenous and exogenous factors that underlie them. They claim that alertness has a high exogenous component, and will therefore show an immediate partial adjustment whereas reaction time, having a large endogenous component, will adjust relatively slowly. This has implications for how organisations run their shift systems; for some tasks it may be better to run permanent shifts to maximise adjustment whereas other tasks may need rapidly rotating systems to minimise adjustment.

Shiftworkers and Bright Light

It is clear from the literature that bright light exposure at an appropriate time of day, for the right length of time, can indeed phase shift human circadian rhythms. However, many organisations using shift schedules now employ a system of rapid rotation, where the incumbent works a different shift every few days, or even daily. In this situation it is unlikely that bright light would be used to readjust circadian rhythms as this would not be useful to rapidly rotating shiftworkers who wish to minimise adjustment. In this case bright light could be employed for its well known immediate alerting effects. As reported earlier, Folkard and Totterdell (1991) claim that alertness has a high exogenous component which means it should show an immediate partial adjustment to an external stimulus such as bright light. Studies show that bright light whether being used to alter circadian rhythms or simply for its immediate alerting effects can increase nighttime performance.

Campbell and Dawson (1990) undertook a study where 25 participants completed several performance tasks under low-level light (10 to 20 lux) for 8 hrs. On the second night participants performed the same tasks under either medium light (100 lux) or bright light (1,000 lux). No pre-exposure occurred and the lights were on for the entire duration of the tasks. Tasks included logical reasoning, spatial manipulation, processing abilities, and a four-choice reaction time task. Those participants in the bright light condition maintained significantly higher levels of alertness and showed improved cognitive performance compared to those in the other two light conditions.

In another study examining the effects of bright light on alertness and performance, Daurat, Aguirre, Foret, Gonnet, Keromes, and Benoit (1993) exposed 8 participants (two groups of four) to bright light (2,000 to 2,500 lux) and dim light (< 150 lux) over 2 nights. Data on performance measures such as letter cancellation, logical reasoning, and visual discrimination were collected over a 12-hr night period, as well as EEG vigilance, rectal temperature, and wrist motor activity. There were statistically significant increases in objective and subjective alertness and improved performance in the bright light condition. The bright light condition showed that the circadian trough of motor activity was delayed by two hrs but did not modify the usual 24-hr pattern of body temperature.

Badia, Myers, Boecker, and Culpepper (1991) investigated the effects of bright light on 44 participants under four conditions. The first condition was a nighttime condition with an alternating bright light (5,000 lux) and dim light (50 lux) condition. The second condition was similar to the first but run during the day. The third and fourth conditions were either continuous bright light or dim light throughout the night. Measures included temperature, EEG alertness, sleepiness, and behavioral tasks (digit recall, logical reasoning, two-letter search, two-column addition, serial addition-subtraction, and a continuous performance task). Performance was better under the alternating nighttime condition and significantly so for digit recall and serial addition-subtraction. Unexpectedly, no significant effects were found under the continuous bright light condition for behavioral tasks. Temperature increased significantly under the bright light condition, and increases were noted within 30 mins of exposure. Sleepiness scores were significantly higher under the bright light condition. It was concluded that nighttime ambient light levels have a substantial effect on physiology and behavior.

While many studies have used bright light in a continuous fashion, Dawson and Campbell (1991) conducted a 3-day experiment using a 4-hr pulse of bright light (6,000 lux) on the first night. Participants were exposed from 2400 hrs to 0400 hrs and were measured for differences in amount of sleep and alertness. On the two subsequent nights, participants were exposed to dim light of < 200 lux. By the third night shift, the phase position of the core body temperature rhythm for the treatment group had delayed by 5-6 hrs whereas the control group had delayed by only 2-3 hrs. 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. The treatment group got, on average, 62 mins more sleep than the control group, which was explained by increased ability to maintain sleep, rather than faster sleep onset. The treatment group maintained their alertness across the night with the first drop at 0700 hrs as opposed to 0300 hrs for the control group.

Thessing, Anch, Muehlbach, Schweitzer, and Walsh (1994) also used a 4-hr pulse of bright light to examine effects on sleepiness and performance over two nights. The study included three conditions. First, bright light for 4 hrs (9,300 lux), second, dim light for 4 hrs (315 lux), and third, a condition in which bright light and dim light were alternated for 2 hrs each. Participants were exposed between 2400 hrs and 0400 hrs on the first night and maintained wakefulness until 0800 hrs at which time they slept through until 1600 hrs. On the second night, no exposure occurred, but participants performed a simulated assembly line task and data were collected on sleepiness levels. Performance was significantly improved in the 4-hr bright light condition but not in the alternating or dim light conditions. Sleepiness increased as the night progressed in all conditions but levels were significantly decreased in the 4-hr bright light condition.

The most recent bright light research, conducted by Baker (1999), aimed to find out if different durations of bright light exposure influenced work performance and whether light intensity and duration trade off. Secondly, the study aimed to more accurately pinpoint the minimum light intensity necessary to yield performance increments.

Baker (1999) used five performance tasks: recall and recognition memory, logical reasoning, vigilance, and numerical reasoning. A number of studies (Campbell & Dawson, 1991; Thessing et al., 1994; Myers & Badia, 1993) found statistically significant effects when comparisons were made across varying light intensities for mental performance, sleepiness, alertness, and melatonin secretion. Furthermore, these studies showed that bright light does have an impact on some types of performance tasks including tasks with a strong cognitive component. Therefore, Baker predicted that her study would show performance effects in the presence of bright light.

Also based on previous studies (Lewy et al., 1980; McIntyre et al., 1989), Baker (1999) anticipated that duration of light exposure would influence task performance. Studies with exposure times falling between 30 and 60 mins found statistically significant reductions in melatonin secretion (Lewy et al., 1980; McIntyre et al., 1989).

Sixteen participants were exposed to four levels of light intensity: baseline (<100 lux), 300, 600, and 1,000 lux, and two levels of duration (15 and 60 mins). Each participant was exposed to all 4 levels of light, one level each week for four consecutive weeks. The 16 participants were split into two groups of eight and exposed for either 15 mins or 60 mins duration prior to beginning the tasks. Baker (1999) varied the intensity of the light by seating participants at various distances from the light source. The actual output of the light source itself remained constant (c.f. McIntyre et al., 1989; Badia et al., 1991).

Main effects were found for intensity of light on the critical thinking task and on the recognition task. Critical thinking showed significant differences between baseline and 300 lux and between baseline and 600 lux. The recognition task showed significant differences between baseline and 300 lux, and baseline and 600 lux for the 15-min light exposure and between baseline and 600 lux for the 60-min exposure.

There were no main effects for letter cancellation, recall, or the mathematical sums task, though this latter task did show a main effect for completion time, with a significant difference between baseline and 600 lux. There were no main effects for duration and no interaction effects. These results show that light intensity and duration do not interact and, thus, cannot be traded. Baker concluded that tasks such at critical thinking and recognition tasks that tax participants' cognitions are more likely to be sensitive to effects of bright light than those that require less reasoning or lighter memory loads. It was also concluded that the recall task showed few effects due to it being the first task every night when participants were likely to be more alert.

The most surprising result was that the 1,000-lux light level produced no effects on any of the tasks for both accuracy and completion time. Baker (1999) gives a number of possible reasons for this. Firstly, on comparison with McIntyre et al. (1989) melatonin levels may not have been as high in Bakers' study due to a real 1-hr time difference (due to daylight saving being in effect at the time of McIntyre's study) between New Zealand and Melbourne (where McIntyre's study took place). However, both studies were run at the same "clock time". Secondly, shorter exposure time may have produced differences in the results. Thirdly, Baker's study had a small sample size and hence low statistical power. Fourth, due to the manner in which Baker varied light intensity, participants were seated very close (1 m) to the light source in the 1,000-lux condition which may have created stress and discomfort for the participants.

While all of these reasons are plausible, time of testing does not explain why lower light intensity affects performance on some tasks while higher intensity light had no effect. Shorter exposure times may explain some differences, although in similar research Badia et al. (1991) found effects with lighting duration of 90 mins prior to task. Costa, Gaffuri, Ghirlanda, Minors, and Waterhouse (1995) found small effects with 20-mins exposure prior to task and then three more 20-min exposures throughout the night.

Small sample size may have also had an effect though this is unlikely given that small numbers of participants are commonly found in night-work studies. Baker (1999) notes that numbers typically range from 6 to 15 participants due to the difficult circumstances under which night studies like these are conducted.

The possible physical discomfort that Baker's (1999) participants experienced at the 1,000-lux intensity (to a point where one person complained about the brightness of the light) as well as the discomfort over lack of personal space (four people in front of a 1 m long light panel) is of more interest. Baker varied light intensity by seating participants at various distances from the light source. While light intensity has been altered in this way before (McIntyre et al. 1989; Badia et al. 1991), the lights used by Baker were not powerful enough to seat participants further back from the source and still gain the 1,000 lux needed for that condition. Furthermore, the width of the light panel was such that the four participants (tested each night) had to sit close together to be at the right distance to gain the required intensity. Baker suggests that further research is urgently required to compare altering light intensity by moving participants, and holding position of participants constant while varying light intensity at the source. The main purpose of the present study was to investigate these two methods of varying light intensity.

The Present Study

Although the phase shifting and alerting effects of bright light have been clearly demonstrated, the optimal parameters of bright light exposure (duration, intensity, and distance) have not been established. Research to date shows that bright light can affect mental performance during the night, providing significant benefits by reducing the effects of sleepiness experienced after the onset of melatonin secretion. Due to the dose-dependent manner in which bright light suppresses melatonin, it is to be expected that the brighter the light the better task performance will be.

Although much work has being carried out on intensity, little research has been conducted on the duration of light exposure. Most studies that have considered duration (Gallo & Eastman, 1993; Laakso, Hotonen, Stenberg, Alila, & Smith, 1993; McIntyre et al., 1989) have done so in the pursuit of testing what time period is required to suppress melatonin. Studies into bright light and nighttime work performance have focused on the intensity of the intervention, with duration not being an independent variable. To date, the only recorded study found to have considered duration as an independent variable found no significant effects (Baker, 1999). However, Baker exposed her participants to bright light prior to the performance tasks. The present study had a condition where participants were exposed to bright light for the duration of the task. Previous studies (Badia et al., 1991) have found performance effects when participants were exposed for the entire duration of the performance tasks.

It was anticipated that performance effects would be found in the present study under the 60-min continuous duration condition because previous studies have found effects with continuous lighting (Badia et al., 1991). Those that have studied shorter durations of lighting have found small, though non-significant, effects (Costa et al., 1995).

With regards to distance from the light source, no studies could be found which have examined distance as an independent variable. It is surprising that no research has been conducted to find out if varying the intensity of the light at source yields the same results as varying the intensity by moving the participant closer to or further from the light source. A number of factors suggest that the two methods of varying intensity may not yield the same results. For instance, moving away from the light source means that not only does intensity decrease but also that the image of the light source on the retina becomes relatively smaller. Thus, for a participant very close to the source, the latter dominates the environment. However, for a participant far from the light source, the latter becomes a less significant part of the environment affording the onlooker more opportunity to fixate on parts of the environment other than the light source. Since light boxes are being increasingly used to help relieve sleepiness (and winter depression), there are strong practical reasons for finding out whether distance from the light source is a viable means of varying light intensity at the eye.

The main purpose of the present study was to compare altering light intensity by moving participants closer to or further back from the light source, and holding participant position constant while varying the light intensity at the source. A secondary aim of the present study was to find out if duration of light exposure influences task performance. Three intensities of light were used: baseline (<100-lux), 1,000, and 2,000 lux. Two duration periods of 15-min prior to task and a 60-min continuous exposure for the duration of the tasks were also examined. Two distance conditions were studied: a fixed distance condition in which light intensity was altered at the source and the participant was fixed in place, and a moved distance condition where the participant was moved to obtain the required intensity, intensity of the source remaining constant. Intensity, Duration, and Distance were studied in a mixed factorial design. Intensity and Distance were within-groups factors while Duration was a between-groups factor.

METHOD

Participants

Twenty individuals (10 male and 10 female) volunteered to participate in the present study. The ages ranged from 17 to 50 (mean = 27.80). Participants were partially reimbursed for the six trips they were expected to make to the laboratory, each receiving $20.00.

Because of the inconvenient times participants were asked to attend the laboratory, they were allowed some input into which night each week, from Monday to Friday, would be most suitable for them to attend. They attended the same night each week for six consecutive weeks. The study was conducted in two 6-week blocks, with 10 participants per block (20 participants in all). There were 5 groups per block, with 2 participants attending the laboratory each night of the week (Monday to Friday).

Design

Three levels of light intensity (baseline (<100 lux), 1000-lux and 2,000-lux), two levels of duration (15-mins prior and 60-mins continuous exposure), and two levels of distance (fixed position and moved position) were studied in a mixed factorial design. Each participant was exposed to all three light levels for each distance condition. That is, each participant was exposed to baseline, 1,000, and 2,000 lux at both fixed and moved distance conditions. The duration factor was studied as a between-groups factor. The first 6-week block (10 participants) was randomly assigned as the 15-min prior condition and the second 6-week block (10 participants) the 60-min continuous condition.

Three levels of lighting were used with each of the two distance levels (within-group factors) and two durations (between-group factor). The 20 participants were randomly assigned to either the first 6-week block or the second 6-week block. They were then randomly assigned to a 2-person group and if no preference of night was indicated, the group was randomly assigned one night of the week to attend. For each block, the light levels were randomly assigned to 1 of 3 weeks and the reverse order was used for the second 3 weeks to provide a counterbalancing effect. Distance conditions were randomly assigned to a light level and a particular week, they were then counterbalanced. For example: Week 1 of the first block was assigned the 2,000-lux light level and the fixed distance condition. The first two nights of the week were whatever was randomly assigned (in this case the fixed distance condition) and the last 3 nights of the week used the moved distance condition. The reverse was true for the 2,000-lux, moved distance condition. For week 2, for two nights the moved distance condition applied whereas on the last 3 nights the fixed distance condition was used. (A schedule of the groups and order of conditions for each block is shown in Appendix A.)

A 2-week interval between weeks 4 and 5 on both 6-week blocks occurred due to university holidays. There was also a break of 1 week between blocks 1 and 2 in order to prepare for the second block. Assignment of conditions and counterbalancing procedures in block 2 were identical to the first 6-week block (Appendix A).

Two different duration exposure groups (15-min prior and 60-min continuous) meant that the participants in the first block (15-min prior condition) commenced their exposure to light at 2345 hrs. Those in the second block did not commence their exposure to light until 2400 hrs. However, as temperature and sleepiness levels were recorded at 2345 hrs, all groups were at the laboratory a little before this time each night (see Appendix B for Sleepiness, Demographic Questionnaire, Temperature, and Test Scoring Form). After measuring temperature and assessing sleepiness, the participants then sat at tables with the baseline light intensity until 2400 hrs when they began their exposure. Those in the 15-min duration condition, after having their temperature taken and sleepiness levels assessed, went directly in front of the bright lights. On the nights when groups were exposed to the baseline condition, they remained at the tables for the full 15-mins, before commencing testing at midnight. All testing was completed at the same tables, regardless of whether participants were exposed to bright light or the baseline condition.

On the first night of each 6-week block, the study commenced at 2330 hrs to give participants time to familiarise themselves with the laboratory and the performance measures. It was decided not to give participants a practice week as Baker (1999) did, because they were already coming to the laboratory for 6 weeks, which was deemed to be a large commitment. Also, it was thought that another week would add to the possibility of practice effects in the present study.

Demographic information was collected on the first night of the each 6-week block only. Participants were given an information sheet (Appendix C) to read if they had not already done so, and a consent form (Appendix D) was then completed. (All procedures used in the present study were approved by the Massey University Human Ethics Committee.)

The tasks took all groups no less than 45 mins and no more than 50 mins to complete each night. To ensure consistency across all 6 nights, standardised instructions (Appendix E) were used. Temperatures and sleepiness levels were recorded again at the completion of the tasks.

Apparatus

Twenty broad-spectrum tubes (Power Twist Duro-Light, 40W) were used to provide the bright light. Exposure to white or full-spectrum light of sufficient intensity at night is believed to rapidly suppress melatonin production (McIntyre et al., 1989).

The lights were placed horizontally on a specially designed frame, measuring 97cm x 133cm, behind a purpose-built diffusing screen (Figure 2). The frame was designed so that the distance from the floor to the bottom of the frame matched the distance from the floor to the desktop that participants were seated at while doing their tasks. This allowed for optimum exposure. Participants were seated at the appropriate distance from the lights depending on which light intensity and distance

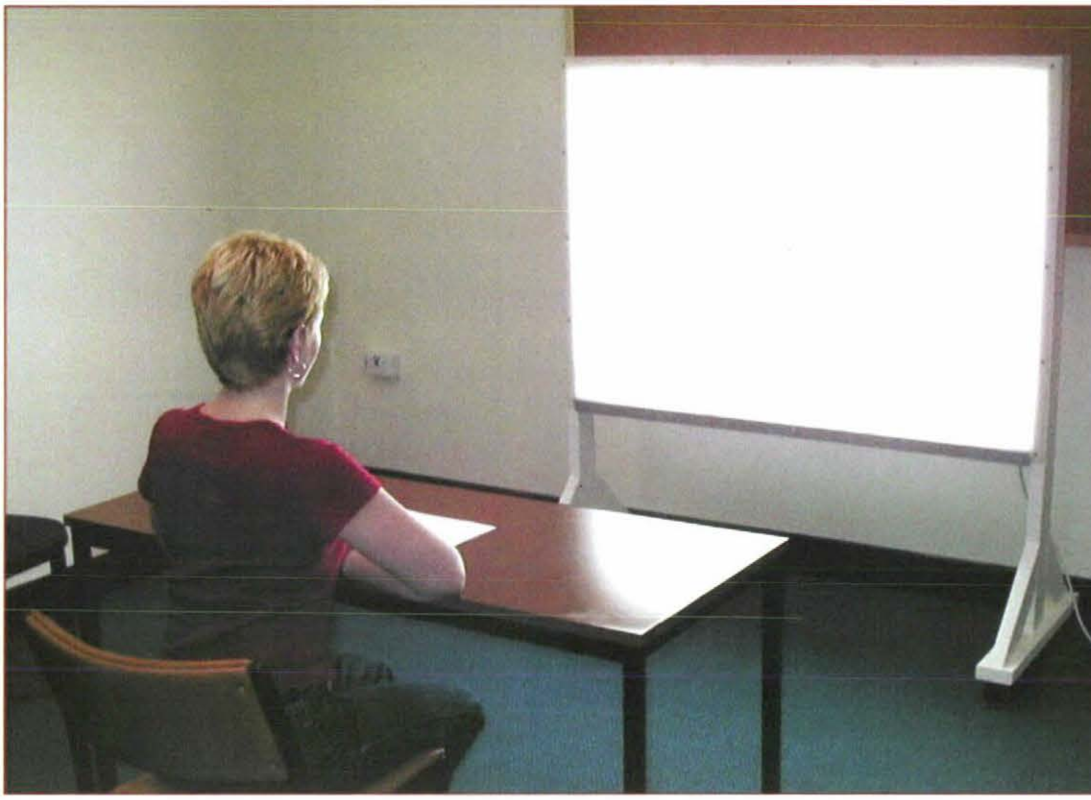

Figure 2: Light Box and Participant Positioning.

condition was being studied. For the moved distance condition, participants were seated at 305 cms and 178 cms from the light panel for the 1,000-lux and 2,000-lux conditions, respectively. Extra diffusing screens were added in front of the light tubes to maintain the required intensity. For the baseline condition, participants were seated 178 cms from the source. Although this actually made no difference (because the light source was ambient room light), it was done for the sake of consistency. For the fixed distance condition, participant position was held constant at 220 cms for all light intensities including the baseline and no extra diffusing panels were used. Prior to the study, the distance from the lights for the baseline (< 100 lux), 1,000 and 2,000-lux conditions was measured and tape was placed across the floor marking the seating positions (see Table 1).

Table 1

Seating Distances (cms) from the Light Source for the Fixed and Moved Distance Conditions

	Intensity (lux)		
	Baseline (<100)	1,000	2,000
Fixed Distance	220 cms	220 cms	220 cms
Moved Distance	178 cms	305 cms	178 cms

On each night, the light levels were checked again by holding a lux meter (Dick Smith digital lux meter, accuracy ± 5 %) close to participants' eyes (Figure 3). The seats were moved slightly from the taped markings when required to ensure the appropriate light levels were maintained. Each chair had an adjustable, built-in headrest, to help participants maintain their head position (this is not shown in Figure 2).

The room light was used for the baseline condition. A dimmer switch allowed the room light to be kept at less than but close to 100 lux. This level was checked each night before commencing the performance tasks and just before 2400 hrs on the nights where the baseline condition was the condition for that night.

Body temperature was obtained using a Braun ThermoScan Instant Digital Thermometer (Figure 3), which provided temperature in degrees Celsius with a resolution of 0.1 degrees. The thermometer probe is inserted into the participant's ear and records the body temperature from the eardrum by "detecting heat from the eardrum and surrounding tissue" (Braun Corporation, undated). Recording the core body temperature, the ThermoScan thermometer takes 1 sec to make a reading using the infrared heat given out by the eardrum. The eardrum sits close to the hypothalamus, sharing the same blood supply. The hypothalamus is the temperature control centre of the brain and due to the ears proximity to it, the method is considered more accurate than oral or rectal techniques.

Figure 3: Braun ThermoScan Thermometer, DSE Digital Lux Meter, and DSE Digital Stopwatch.

Measures

Subjective Sleepiness

The Stanford Sleepiness Scale (Hoddes, Zacrone, Smythe, Phillips, & Dement, 1973) was used to determine the subjective sleepiness of participants at 2345 and 0100 hrs. It has been found that the Stanford Sleepiness Scale's ability to measure sleepiness is "highly correlated" with performance on tasks found to be sensitive to moderate amounts of sleep loss. Although the scale was developed 28 years ago, it is still in use as a valid measure of subjective sleepiness in research as recently as the study by Leproult, Van Reeth, Byrne, Sturis, and Van Cauter (1997). Baker (1999) who investigated the effects of bright light on performance at night in the same laboratory as the present research also used the scale.

Participants were requested to select the statement that best described how they felt at each particular time each night. Scoring values range from 1 (Feeling active and vital; alert; wide-awake) to 7 (Almost in reverie; sleep onset soon; lost struggle to remain awake) (Hoddes et al., 1973).

Temperature

Body temperature was obtained using the ThermoScan Thermometer at 2345 hrs (before exposure to the light condition) and at 0100 hrs (immediately after completion of performance tasks). Baker (1999) took temperature readings three times during the night, but got very little variance between times of testing. Therefore, it was decided that it was only necessary to take temperature readings twice. Also because of the continuous light condition in the present study, it was felt that taking temperature at 2345 hrs (before exposure) then at 2400 hrs, again before exposure, was a double up of information. A clean cap was used on the temperature probe for each measurement recording for reasons of hygiene.

Performance Measures

Due to this study being a replication and extension of Baker (1999), it was decided that the present study would use the same performance tasks in order to make direct comparisons. After a review of sleep deprivation on performance, Baker decided that cognitive performance decreases were more pronounced in short tasks than on long tasks, following sleep deprivation of less than 45 hrs. In the present study, participants would be deprived of some sleep but substantially less than 45 hrs, so performance tasks were kept to a completion time of between 5 and 10 mins.

The tasks were designed by Baker (1999), based on previous research where statistically significant deficits for mental performance at night had been found. Five performance tests were used: Word recall, mathematics exercises, two-letter cancellation, word recognition, and critical thinking appraisal.

In Baker's (1999) study, the 25 words used in the recall task were also the target words in the recognition task. To minimise interference between recall and recognition the recall task was always the first task and the recognition task the last. The other three tasks were randomly assigned an order in between the recall and recognition tasks.

Baker (1999) developed four versions of each task and a practice task, the latter being used as a study task in the present study. The present study required six versions of each task so Baker's practice tasks were used for week 1 and repeated for week 6, except for the word recognition and recall tasks for which new word lists were developed for use in week 6. No practice tasks were used in the present study. However, participants were able to briefly examine the type of tasks they would be asked to perform during the sessions when they arrived for the first night of the study. It was decided that it was unlikely that participants would remember answers to mathematical sums or positions of letters in the letter cancellation task after a 6-week period but that they may remember word groupings. (Appendix F contains examples of all tasks.)

Word Recall Task

The 25 four-letter words that made up each of the word recall tasks were randomly chosen from Thorndike and Lorge's (1944) book of "The teacher's workbook of 30,000 words". Parameters for selection of words were established to ensure the words used were neither too common nor too obscure. Only words used more than 20 times per 1,000,000, but less than 100 times per 1,000,000 were included. Names of people and places were excluded.

Five separate word recall tasks were compiled for use on Baker's (1999) study, including a practice task. One more was compiled for the present study, to cover each of the 6-week periods. That is, a new set of words was used each week, none being repeated. Participants were given a list of the 25 words and asked to read over the list for 1 min. The experimenter then read each word out, with a momentary pause for approximately 1 sec, and instructed participants to concentrate on each word as it was spoken. A further 30 sec was given to read over the list again. Participants were then instructed to turn the paper over and to write down in any order as many of the words as they could remember in the 1-min time frame given. The number of correct words was the dependent measure.

Word Recognition Task

From the 25 words presented in the Word Recall Task, each word was paired with another randomly chosen four-letter distractor word from the selection pool. The order of the 25 words was randomised from the order they had appeared in the Word Recall Task. Participants were instructed to cross out the word in each pair that they had previously seen that night in the Word Recall Task. The experimenter read each word pair out aloud and then paused momentarily for approximately 2 s. During this pause, participants were instructed to cross out the word they believed they had seen previously.

Including the practice exercise that Baker (1999) compiled, there were 5 tasks compiled for the Recognition Task. These were used in the present study and one further task was compiled in the same manner as above to cover all 6 weeks. Percentage of correct decisions was the dependent measure.

Mathematical Sums Task

Baker (1999) developed a total of 32 sets of adding, subtraction, and simple multiplication exercises. Even numbers of additions, subtraction, and multiplication exercises were used on each of the 6 nights. The difficulty of the sums were kept constant across the tests, with the same number of double and triple digit sums, and long addition sums appearing in each night's tests. Including a practice task, Baker compiled 5 sets of mathematical sum tasks. The present study used the exercises over the two 6-week blocks with exercise 1 being presented at weeks 1 and 6 for the first block and weeks 7 and 12 of the second.

Calculators were not allowed but scrap paper was provided for those who needed it. Participants were asked to complete the sums as quickly and as accurately as possible. Completion time and percentage of correct responses were the two dependent measures.

Letter Cancellation Task

Pencil and paper tests of vigilance, such as the letter cancellation task, appear to be effective at detecting performance deterioration due to sleep loss and circadian factors (Porcu, Bellatreccia, Ferrara, & Casagrande, 1998). Casagrande, Violani, Curcio, & Bertini (1997) state that the two-letter cancellation task is the most effective for determining sleep deprivation effects because it is less subject to variations with practice and because it is completed quickly. The use of three or more letters in the cancellation task tends to show greater error variability.

The letter cancellation task requires participants to search and mark sequentially, reading from left to right and top to bottom as fast and accurately as possible, two target letters within a 36 x 50 matrix of capital letters (Font: Times New Roman, 12 in). A total of five separate pages of 1800 randomly selected letters were compiled for Baker's (1999) study. The present study used these exercises over the two 6-week blocks with exercise 1 being presented in weeks 1 and 6 in the first block and 7 and 12 in the second. The target letters in each of the five tasks appeared 150 times, with a total correct score of 300. The completion time, number of hits, and number of false positives were recorded.

Critical Thinking Task

The Watson-Glaser Critical Thinking Appraisal (CTA) was utilised in the present study as in Baker (1999). The CTA is made up of five separate sections: Inference, Recognition of Assumptions, Deduction, Interpretation, and Evaluation of Arguments. One of the 5 sections was used each night. The inference section was used twice per block on weeks 1 and 6 and weeks 7 and 12. It was thought that placing them in the first and last weeks of each block would control for practice effects. The other 4 tests were randomly assigned to each week in the order above.

Reliability of the CTA has been established using split half reliability, with correction for test length obtained, using the Spearman-Brown formula. Coefficients range from .76 to .82. Reliability over time was obtained by administering the test to 2 groups of college students (N = 96) with a 3-month interval between testing. Means and standard deviations for the 2-test period were extremely close, with test 1 showing a mean of 57.4 (SD 8.1) and test 2 showing a mean of 56.8 (SD 8.4) (Watson & Glaser, 1980).

The validity of the CTA has been established in a number of different settings. It has been found to measure a sample of the specified objectives of a number of instructional programmes, which is an indication of its content validity. Construct validity has been established by measuring the assumption that exposure to programmes that improve critical thinking should be reflected in CTA scores (Watson

& Glaser, 1980). Fogg and Calia (1967) found improvement on CTA scores following a 2-yr study into students' critical thinking abilities.

The CTA has been found to correlate with other tests, including the Stanford Achievement Tests, general intelligence tests, and grade point averages. Watson and Glaser (1980) found that the CTA reflected a dimension of intellectual functioning that was independent of that measured by specific intelligent tests. This has been substantiated by Comrey (1974, cited in Watson & Glaser, 1980) who, in analysing a large sample of high school and college students that had completed the CTA, stated that the CTA measures a unidimensional aspect of ability which provides evidence of the test's internal consistency.

The scores on the CTA subsets are related to the total score, with correlation's of between .55 and .68 across all of the 5 tests on tests. The present study recorded both correct responses and completion times.

Procedure

The study commenced at 2345 hrs each night. Those in the first block (15-min prior condition), were required to sit for the specified time period in chairs with headrests, facing the lights and positioned at the designated distance from them. Those in the second block (60-min continuous condition) sat anywhere (in chairs, on the floor) until 2400 hrs when they moved into the chairs and began their exposure to light.

Positions of the chairs were checked for the appropriate level of light and any small adjustments were made. Participants were instructed to look into the lights at least every couple of minutes, keeping their heads against the headrest. They were also instructed not to move the chairs. The experimenter was present at all times and participants were frequently asked to remember to look at the lights. Participants in the first block (15-min prior) were able to read, talk, or listen to music while the light exposure took place as long as they did not obscure their faces in any manner. Those in the second block were able to do as they pleased in the laboratory until light exposure began.

After 15 mins of light exposure (for those in the 15-min prior group) the lights were switched off (at 2400 hrs) and participants began the exercises under normal room lighting (< 100 lux). Those in the second block moved to work tables and began their exposure to light and the performance tasks at 2400 hrs. Standardised instructions, the same used in Baker (1999), were read aloud to each group at the appropriate time for each task. The instructions included what was expected of the participants at different stages during the experimental conditions and what was required of them for each task. Questions were invited and answered immediately.

Statistical Analysis

All raw data were input into the Statistical Package for the Social Sciences, version 8 (SPSS Inc., 1998). This was used to calculate all descriptive statistics, carry out MANOVAs, and calculate correlations for speed/accuracy tradeoffs. Where required, *t*-tests were carried out and these were calculated by hand.

Temperature and sleepiness levels data were not analysed because preliminary analysis showed no effects of Intensity, Duration, or Distance. Baker (1999) also found no significant effects for either temperature or sleepiness levels. However, it was decided to continue collecting the data for consistency and to replicate the procedure of Baker.

Demographic information on gender was collected to ensure that an even mix of males and females participated in the study. The participants' age information was collected to obtain the range, mean, and SD data. No other analyses were done on this information.

RESULTS

Speed - Accuracy Tradeoff

For the mathematical sums tasks, the letter cancellation tasks, and the critical thinking tasks both completion time and accuracy were used as dependent measures. The data were checked for speed-accuracy tradeoffs that would show up as a set of negative correlations between the speed and accuracy measures for each task. Table 2 presents the correlations between completion time and levels of accuracy on the three tasks. The data are collapsed across all 12 sessions and both durations.

Statistically significant negative correlations were found between speed and accuracy in regards to the mathematical sums task and the critical thinking task: the faster the participants completed the task the less accurate their scores, and vice versa. In fact, all of the correlations for these two tasks were negative, although just three of them reached the conventional ($p = .05$) level of significance. In these three cases at least, caution is required when interpreting results from both tasks given these speed-accuracy tradeoffs.

For the letter cancellation task, positive correlations were unexpectedly found for all conditions. That is, as speed increased so did accuracy. However, none of these correlations were significantly different from zero.

Given the speed-accuracy tradeoffs, treating speed (or accuracy) as a covariate was considered. However, both speed and accuracy are variables affected by the

Table 2

Correlations Between Speed and Accuracy for Mathematics, Letter Cancellation, and Critical Thinking, Collapsed Across all 12 Sessions and Both Durations

	Intensity (lux)		
Task	Base	1000	2000
	Fixed Distance Condition		
Mathematics	-.785**	-.064	-.370
Letter Cancellation	.209	.007	.324
Criticial Thinking	-.218	-.116	-.552*
	Moved Distance Condition		
Mathematics	-.196	-.514*	-.242
Letter Cancellation	.289	.087	.411
Critical Thinking	-.308	-.542*	-.350

* Significant at .05
** Significant at .01

experimental manipulations. Under such circumstances, Hays (1973) advises against a covariance analysis, writing, "...when the concomitant variable is itself affected by the experimental treatment, adjusting the means of the dependent variable may actually remove some portion of the treatment affects themselves" (p. 658). To date, very few studies have been found that have raised the speed-accuracy issue or done anything to combat it. There seems to be no satisfactory means available for handling the dependency between the two variables of speed and accuracy. All that can be done is to note any relationships and interpret findings cautiously.

Performance Tasks

The performance tasks were analysed using Multiple Analysis of Variance (MANOVA: SPSS, 1998). Where there was a main effect involving the three levels of intensity, or where there was an interaction effect, follow-up *t*-tests were conducted to locate the main source of the effect. Homogeneity of variance was checked using Mauchly's Test of Sphericity (SPSS, 1998). In every case, sphericity was assumed as the significance level exceeded the conventional ($p = .05$) level of significance.

Word Recall Task

The word recall task was scored out of a possible 25. The means (M) and standard deviations (SD) for all Intensity, Duration, and Distance conditions are shown in Table 3 as percentage scores.

Table 3 suggests that Distance had little or no effect on word recall; Duration also appears to have had little effect. It is interesting to note that both the highest and lowest mean scores are found in the 2,000-lux/moved condition with M = 58.00 and M = 36.90 for the 15-min and 60-min groups, respectively. Even more interesting is that scores were always higher in the 15-min group compared with the 60-min group.

The MANOVA results confirm these impressions. No main effects were found for Distance $F(1,18) = .68$, $p = .42$, Duration $F(1,18) = 2.20$, $p = .15$, or Intensity $F(2,36) = .29$, $p = .73$, although a two-way interaction was found for Intensity and Duration, $F(2,36) = 4.24$, $p = .03$.

Table 3

Word Recall Task Mean (M) and Standard Deviation (SD) Percentage Scores for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
	Fixed Distance Condition		
15-min			
M	46.00	50.40	51.60
SD	16.02	17.50	13.39
60-min			
M	42.80	43.60	40.80
SD	14.48	12.42	10.63
	Moved Distance Condition		
15-min			
M	47.20	51.20	58.00
SD	14.08	13.57	14.97
60-min			
M	46.80	39.60	39.60
SD	18.18	15.13	11.84

Examining this interaction for simple main effects, *t*- tests revealed that those in the 15-min group had better recall than those in the 60-min group at both intensity levels of 1,000-lux, $t(18) = 2.06$, $p < .05$, and 2,000-lux, $t(18) = 4.04$, $p < .005$. As expected, there was no difference between the two duration groups at the baseline intensity $t(18) = .36$, $p > .05$.

Word Recognition Task

It will be recalled that participants studied 25 words at the start of the experimental session. The last task they had to perform in the session was to recognise the 25 words previously shown (targets) which were embedded in a set of 25 words not previously seen (distractors). The method of presentation in the recognition task was a two-alternative, forced-choice method where one target and one distractor were shown as a pair. Table 4 shows the mean (M) recognition scores for all experimental conditions along with their associated standard deviations (SD).

It can be seen that mean recognition scores were higher in the 15-min group compared to the 60-min group for both the 1,000-lux and 2,000-lux light levels at both distances. However, a MANOVA revealed that the outcome was somewhat more complex.

There was a three-way interaction, $F(2,36) = 5.60$, $p = .01$, but no main effects. A more detailed analysis of the three-way interaction between Intensity, Duration, and Distance indicated that scores in the fixed distance condition were significantly higher than those in the moved distance condition, but only in the 60-min group at the 1,000-lux intensity, $t(18) = 5.00$, $p < .01$.

Table 4

Word Recognition Task Mean (M) and Standard Deviation (SD) Percentage Scores for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
	Fixed Distance Condition		
15-min			
M	88.00	93.00	91.20
SD	9.04	5.90	7.95
60-min			
M	91.20	93.20	84.40
SD	9.00	4.23	6.38
	Moved Distance Condition		
15-min			
M	86.80	93.20	91.60
SD	8.85	5.97	7.16
60-min			
M	91.20	84.40	87.20
SD	8.80	6.65	13.83

Mathematical Sums Task

Results for the mathematical sums task, especially the size of the standard deviations, must be interpreted cautiously due to possible ceiling effects (see Table 5). The measure consisted of 32 mathematical sums and most people scored in the top range, making the means high and possibly truncating the standard deviations. Furthermore, it will be recalled that there was a speed-accuracy tradeoff for this task (see Table 2).

Accuracy

The mathematical sums task was scored out of a possible 32. The means (M) and standard deviations (SD) for all Intensity, Duration, and Distance conditions are reported in Table 5 as percentage scores.

No main effects were found for Distance $F(1,18) = .926$, $p = .34$, Duration $F(1,18) = .370$, $p = .55$, or Intensity $F(2,36) = .915$, $p = .40$. No interaction effects were found for the mathematical sums task, although a two-way interaction between Distance and Intensity approached significance, $F(2,36) = 3.22$, $p = .06$. Although this interaction did not quite reach the conventional level of significance, specific contrasts (using *t*-tests) showed a statistically significant difference between the fixed and moved distance conditions at the 1,000-lux intensity level, $t(18) = 1.98$, $p < .05$, with participants in the fixed distance condition scoring higher than those in the moved distance condition.

Table 5

Mathematical Sums Task Mean (M) and Standard Deviation (SD) Percentage Scores for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
		Fixed Distance Condition	
15-min			
M	93.43	90.62	90.00
SD	7.71	7.51	9.29
60-min			
M	89.37	92.62	91.25
SD	10.22	4.46	8.30
		Moved Distance Condition	
15-min			
M	90.93	86.25	91.56
SD	5.59	11.52	6.42
60-min			
M	94.68	88.75	92.50
SD	4.89	10.84	7.54

Figure 4 depicts this interaction. It can be seen that performance in the fixed distance condition increased while that in the moved distance condition dropped considerably at 1,000 lux.

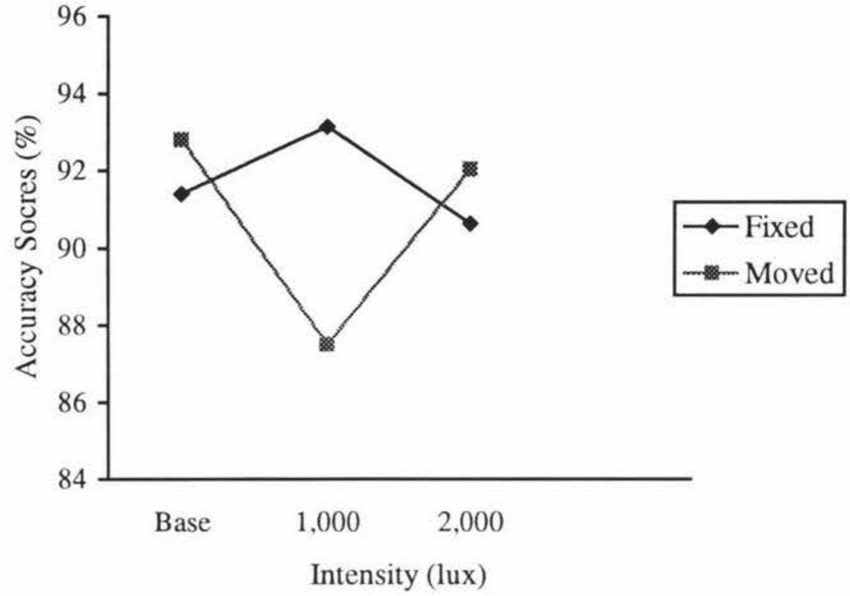

Figure 4 : Two-way interaction between Intensity and Distance for the Mathematical Sums Task (collapsed across Duration)

Completion time

The time it took participants to complete the mathematical sums task was recorded to the nearest minute. Table 6 shows the means (M) and standard deviations (SD).

The 15-min duration condition produced the fastest completion times. The two fastest completion times were found in the baseline/15-min/fixed distance condition, M = 5.87, and in the 2,000-lux/15-min/moved distance condition, M = 5.64.

Table 6

Mathematical Sums Task Completion Time Mean (M) and Standard Deviation (SD) for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
	Fixed Distance Condition		
15-min			
M	5.87	6.65	7.51
SD	1.68	1.51	2.04
60-min			
M	9.54	7.39	7.93
SD	4.27	3.31	3.29
	Moved Distance Condition		
15-min			
M	6.05	7.37	5.64
SD	1.84	2.04	1.37
60-min			
M	7.40	8.39	7.37
SD	3.83	2.98	3.69

There was a main effect for Distance, $F(1,18) = 9.39$, $p = .01$, and an interaction between Intensity and Duration, $F(2,36) = 7.83$, $p = .002$. However, this two-way interaction was embedded in a three-way interaction, $F(2,36) = 11.90$, $p = .001$. The three-way interaction, qualifying the main effect for distance, revealed significantly faster scores in the moved distance condition for those in the 15-min group at the 2,000-lux intensity, $t(18) = 3.29$, $p < .001$, compared to the fixed distance condition/60-min group, as the main source of the variance.

Letter Cancellation Task

Positive (though statistically non-significant) correlations were found for all intensity levels of this task in the speed-accuracy trade off analysis (see Table 2). This interaction should be kept in mind when interpreting the following.

Accuracy

The letter cancellation task was scored out of a total possible score of 300. False positive results were not analysed as they amounted to less than 1% of the letters cancelled for each participant. Percentage scores are recorded in Table 7.

The 1,000-lux/60-min/fixed distance group produced the highest mean score of 96.35, while the lowest mean scores were found for the baseline/15-min/moved distance group (91.40), and the baseline/15-min/fixed distance group (91.60).

MANOVA revealed a main effect for Intensity, $F(2,36) = 4.73$, $p = .02$, while the main effect for Distance approached significance $F(1,18) = 3.95$, $p = .06$. For the main effect of Intensity, *t*-tests revealed significant differences between the baseline and 1,000-lux levels, $t(18) = 5.12$, $p < .005$, and between the baseline and 2,000-lux levels, $t(18) = 4.46$, $p < .005$.

Table 7

Letter Cancellation Task Mean (M) and Standard Deviation (SD) Percentage Scores for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
	Fixed Distance Condition		
15-min			
M	91.60	95.07	95.08
SD	6.31	2.24	2.63
60-min			
M	94.67	96.35	94.53
SD	4.19	2.29	6.27
	Moved Distance Condition		
15-min			
M	91.40	92.66	95.27
SD	4.92	6.25	3.72
60-min			
M	93.07	95.17	94.27
SD	6.47	3.48	4.06

Completion Time

The time it took participants to complete the Letter Cancellation task was recorded to the nearest minute. Means (M) and standard deviations (SD) are shown in Table 8.

Those in the 2,000-lux/moved distance condition had the fastest completion time of 8.31 mins, while those in the baseline conditions produced the slowest times.

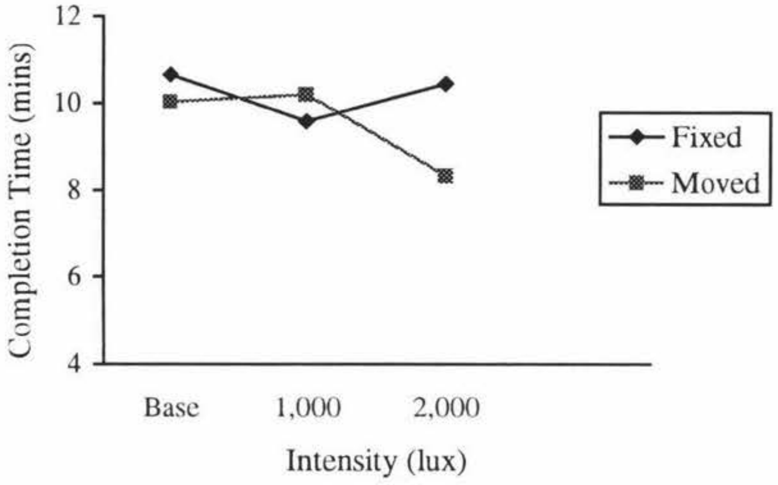

Figure 5: Intensity by Distance Interaction for the Letter Cancellation Task Completion Time for the 15-min Group

MANOVA revealed a three-way interaction between Distance, Intensity, and Duration, $F(2,36) = 3.86$, $p = .04$. The moved distance condition participants performed significantly faster than those in the fixed condition but only in the 15-min group at the 2,000-lux intensity, $t(18) = 2.80$, $p < .01$ (see Figure 5).

Table 8

Letter Cancellation Task Completion Time Mean (M) and Standard Deviation (SD) for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
		Fixed Distance Condition	
15-min			
M	10.65	9.57	10.44
SD	2.67	2.26	2.76
60-min			
M	11.25	9.54	10.64
SD	4.87	3.47	4.96
		Moved Distance Condition	
15-min			
M	10.03	10.19	8.31
SD	2.98	3.03	1.95
60-min			
M	11.39	9.46	10.98
SD	4.44	3.49	3.86

It can be noted that the difference (at 2,000-lux) between the fixed and moved distance conditions is due to an increase in performance speed for the moved distance condition. Performance varied only slightly across light levels for the fixed distance condition.

Critical Thinking Task

Accuracy

The critical thinking task used was scored out of a possible 80. Means (M) and standard deviations (SD) are shown in Table 9 as percentage scores. Recall the speed-accuracy tradeoff reported earlier for this task, meaning that findings should be interpreted cautiously.

Those in the baseline/15-min/fixed distance condition showed the highest mean score (87.50), while those in the 2,000-lux/15-min condition, for both fixed and moved distances, yielded the lowest mean scores of 59.37 and 61.89, respectively.

MANOVA confirmed these differences showing a main effect for Intensity, $F(2,36) = 6.85$, $p = .004$, and two-way interactions for Intensity and Duration $F(2,36) = 23.90$, $p = .001$, and Distance and Intensity $F(2,36) = 4.94$, $p = .02$.

The two-way interaction between Intensity and Duration revealed a complete cross over in the interaction. The 15-min group performed better at the 1,000-lux intensity, $t(18) = 2.94$, $p < .005$, while the 60-min group were more accurate at the 2,000-lux level, $t(18) = 4.62$, $p < .005$ (see Figure 6).

The Distance by Intensity interaction was caused by differences at the baseline level of intensity, where a significantly higher score was found for the fixed Distance condition compared to the moved distance condition, $t(18) = 2.27$, $p < .01$.

Table 9

Critical Thinking Task Mean (M) and Standard Deviation (SD) Percentage Scores for all Intensity (lux), Duration (min), and Distance conditions

	Intensity		
Duration	Baseline	1000	2000
	Fixed Distance Condition		
15-min			
M	87.50	78.12	59.37
SD	7.21	11.50	20.46
60-min			
M	82.50	65.00	82.50
SD	10.94	11.48	16.87
	Moved Distance Condition		
15-min			
M	75.00	78.12	61.89
SD	19.54	18.45	15.44
60-min			
M	76.87	65.62	85.00
SD	11.42	10.72	9.86

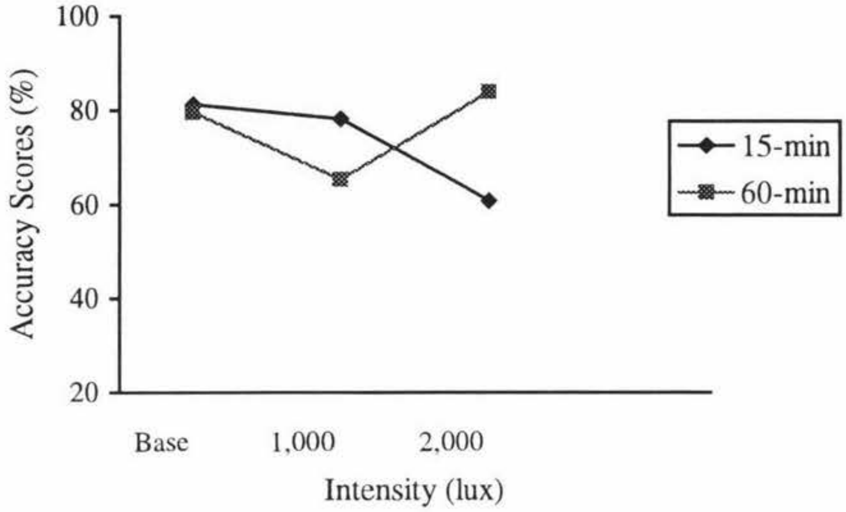

Figure 6: Intensity by Duration Interaction for the Critical Thinking Task (collapsed over the distance condition)

Completion time

The time it took participants to complete the critical thinking task was recorded to the nearest minute. If the participant had not completed the task within the 10-min time frame, they were asked to stop the task and their time was recorded as 10 mins. However, this only occurred for one participant during the study. Means (M) and standard deviations (SD) are given in Table 10.

Those in the 1,000-lux/15-min/fixed distance group had the fastest completion times with a mean score of 3.93, followed closely by those in the 1,000-lux/15-min/moved distance condition, M = 4.89. In every case the 15-min condition revealed faster scores than the 60-min condition, producing a main effect for Duration, $F(1,18) = 4.53, p = .05$.

Table 10

Critical Thinking Task Completion Time Mean (M) and Standard Deviation (SD) for all Intensity (lux), Duration (min), and Distance Conditions

	Intensity		
Duration	Baseline	1000	2000
	Fixed Distance Condition		
15-min			
M	5.25	4.89	6.86
SD	1.24	1.06	2.06
60-min			
M	5.51	6.11	7.30
SD	1.61	.84	1.07
	Moved Distance Condition		
15-min			
M	5.55	3.93	5.55
SD	1.83	2.19	1.73
60-min			
M	6.19	7.78	5.81
SD	1.21	1.15	1.37

However, a three-way interaction $F(2,36) = 5.97$, $p = .01$, qualified this main effect. Exploration of this interaction shows that there was a significant difference between the fixed and moved distance conditions for both the 15-min group, $t(18) = 1.76$, $p < .05$, and the 60-min group, $t(18) = 5.22$, $p < .01$, but only at 1,000-lux intensity. Figure 7 shows the crossover of scores, with the moved distance condition yielding faster scores in the 15-min group, while the fixed distance condition produced faster scores in the 60-min group.

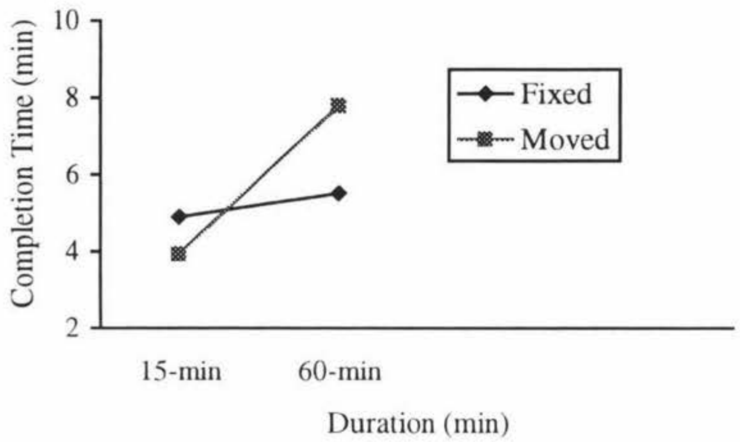

Figure 7: Interaction between Distance and Duration at 1,000-lux Intensity for Critical Thinking Completion Time

DISCUSSION AND CONCLUSIONS

Distance Effects

The main purpose of the present investigation was to find out if changes in the intensity of a bright light source differentially affected nighttime performance when the intensity was varied at the source compared to moving participants in relation to the source. Overall, the results of the present study suggest that the method of varying light intensity does matter if only for the 2,000-lux intensity. In the study conducted by Baker (1999) performance effects were found at moderate light levels of 300-lux and 600-lux but not at 1,000-lux intensity. One reason given for the failure to find any effects at 1,000-lux was the way intensity was varied. Baker chose to vary intensity by altering the distance at which participants were seated from the light so that at the 1,000-lux intensity participants were seated less than 1 m away from the source. Baker suggested that participants were uncomfortable sitting that close to the source. Furthermore, participants had to sit very close to each other in front of the light source, possibly interfering with performance.

Previous research has not studied distance from source specifically as an independent variable. It would seem that altering the intensity of a light source is a simple matter of turning the lights up or down at the source as required. However, given Baker's (1999) study, and the way she chose to vary light intensity this cannot be assumed. The literature to date provides little information about how light intensity was varied, or of how the light source was designed and used. However, both Badia et al. (1991) and McIntyre et al. (1989) varied light intensity in the manner used by Baker. The study by McIntyre et al. revealed the dose-dependent manner in which melatonin was suppressed, while Badia et al. found significant results for two performance tasks: serial addition-subtraction and digit recall. These studies show that the method chosen by Baker is a viable means of varying light intensity.

In general, the findings of the present study do not support Baker's (1999) view that varying light intensity by distance from the light source is cause for concern. In the present study, one main effect was found for distance in the mathematical sums task for completion time, though there was a main effect for the letter cancellation task that did not quite reach the conventional level of significance ($p = .05$). Although all performance tasks, with the exception of word recall, show some distance effects, the fixed distance and moved distance conditions produce performance changes about equally often across all experimental tasks. With this in mind it may be more appropriate to examine the overall pattern of mean differences rather than just the statistically significant results – the approach taken in the following discussion.

The moved distance condition yielded higher scores and faster completion times in five out of nine cases. Four of the interactions involved in these five cases included intensity, and in every case the 2,000-lux level yielded better results (though not necessarily reaching statistical significance). Four of the five interactions included duration, and in each case the 15-min duration condition yielded higher scores and faster completion times. In each case where the results revealed a three-way interaction that included the moved distance condition, higher scores and faster completion times were always at the 2,000-lux intensity and only for the 15-min group. The fixed distance condition yielded higher scores and faster completion times in four out of nine cases. All four of the interactions involved included intensity and in all four cases faster completion times and higher scores were found at the 1,000-lux intensity. Two of the five interactions were three-way interactions. In both cases better performance occurred in the fixed distance condition but only at the 1,000-lux intensity and only in the 60-min group. Therefore, the overall pattern of the results of the present study suggest that the method of altering light intensity had an effect for the moved distance condition in the 15-min group and/or at the 2,000-lux intensity and for the fixed distance condition in the 60-min group and/or at the 1,000-lux level.

Turning now to a more detailed discussion of each individual task. The results for the word recall task are surprising in that it is the only task that failed to show some form of distance effect (though it did show performance effects under bright light treatment). On examination of the intensity and duration interaction for word recall, it can be seen that the 15-min duration group performed better than the 60-min duration group at both 1,000-lux and 2,000-lux intensities. This may be explained by the fact that the 60-min duration group did not receive their exposure prior to task as in the case of the 15-min group. As it takes between 10 and 20 mins of bright light treatment before melatonin levels begin to decrease (Lewy et al., 1980) it almost certainly means that in the early stages of the session (the word recall task was the first task in the sequence each night) the light may not have had time to produce effects. Baker (1999) found that light had no impact on the accuracy of word recall and suggests that the word recall task showed few effects because it was the first task in the sequence each night. However, this should not be the case because both of Baker's duration conditions were designed so that participants would receive bright light treatment prior to task. It is unclear why Baker's study (which like the present study had a 1,000-lux intensity condition and a 15-min prior duration condition) failed to show performance effects when bright light was added, particularly at the 1,000-lux intensity. Also, the manner in which Baker chose to vary light intensity is comparable to the moved distance condition in the present study. Therefore, it is interesting to note that (although not statistically significant) for the word recall task, the 15-min duration group had better recall in the moved distance condition than in the fixed distance condition in every case (see Table 3). One possible reason for this is the seating arrangements in Baker's study. At the 1,000-lux intensity participants may have been seated too close to the lights and each other to be comfortable when doing the performance tasks. However, this does not explain why Baker found no effects at lower light intensities.

For the word recognition task, distance effects were found in the fixed distance condition at the 1,000-lux intensity but only in the 60-min duration group. Baker (1999) found a main effect of intensity for word recognition with differences between the baseline and 300-lux/15-min duration condition, the baseline and 600-lux/15-min duration condition, and between the baseline and 600-lux/60-min duration condition. She found no effects at the 1,000-lux intensity. This may be explained by the fact that performance effects at the 1,000-lux intensity in the present study were found in the fixed distance condition. Baker's method of altering intensity was comparable with the moved distance condition in the present study. However, this does not explain why she should find effects at lower light levels when altering intensity in that manner. The reason suggested by Baker is the seating arrangements at the 1,000-lux level. She believes that participants were too close to the light source and each other to be comfortable doing the tasks.

For the mathematical sums task, accuracy scores show a distance by intensity interaction in which the highest scores were found in the fixed distance condition but only at the 1,000-lux intensity. Baker (1999) found no effects of intensity for the accuracy scores of the mathematical sums task, which is unusual given that mathematical sums task performance has previously been found to improve with light levels of 1,000 lux (Campbell & Dawson, 1990; Myers & Badia, 1993). However, the present study found performance effects only when participants were fixed in place and the light intensity was altered at the source and not when participants were moved, as Baker's were. This, of course, may be the reason that Baker's study failed to show effects for intensity for the mathematical sums task. For completion time, the mathematical sums task showed a main effect for distance, but this was qualified by a three-way interaction, in which the fastest completion times were found in the moved distance condition, but only at the 2,000-lux intensity and only in the 15-min duration group. Baker also found a main effect for intensity for completion time of the mathematical sums task. In her study, the effect was due to a difference between the baseline condition and the 600-lux intensity. As in the present study, effects for completion time were not found at the 1,000-lux level. While the reason for Baker's lack of effects at the 1,000-lux level may be explained by seating arrangements, this explanation is not appropriate for the present study. However, it is interesting to note that in the present study, all of the findings for completion time are at the 2,000-lux level which is backed up by Daurat et al. (1993) who found that letter cancellation completion time improved under bright light of 2,000-lux.

The letter cancellation task (accuracy) shows a main effect for distance although it does not quite reach the conventional level of significance ($p = .05$). A main effect for intensity was also found and was due to differences between the baseline intensity and the 1,000-lux level and between the baseline condition and the 2,000-lux intensity. Baker (1999) found no effects of intensity for the accuracy of the letter cancellation task. However, she ran a 1,000-lux intensity condition that is directly comparable to the 1,000-lux intensity condition in the present study. It is unclear why she did not find effects at this intensity, though it may be due to the finding that there was a difference between the two distance conditions in the present study. It can be seen (Table 7) that the fixed distance condition produced higher scores than the moved distance condition in five out of six comparable mean scores (although this did not produce a statistically significant main effect). Baker's null finding may be explained by the fact that she used a method for altering intensity comparable to the moved distance condition in the present study. The moved distance condition in the present study altered the distance that the participants were seated from the light source as a method of varying light intensity and was directly comparable to Baker's method of varying light intensity. The present study also ran a fixed distance condition that kept participants fixed in one place and varied the intensity of the light at the source and it is in this condition that the general trend of better performance occurs. However, performance effects have been found when researchers have used Baker's method of varying intensity. McIntyer et al. (1989) varied light intensity in the same manner as Baker and revealed the dose-dependent manner in which melatonin is suppressed, and Badia et al. (1991) found significant effects for two performance tasks: serial addition-subtraction and digit recall. Badia et al. did not find significant effects for all of the performance tasks measured in their study. Logical reasoning, two-letter search, two-column addition, and a continuous performance task did not show any differences when bright light was added, which may mean that the effects of bright light are task dependent. Those studies in which participants have been fixed in place and the light intensity altered at the source have also had mixed findings. Campbell and Dawson (1990) found that tasks such as logical reasoning, spatial manipulation, processing abilities, and a four-choice reaction time task were significantly improved under a bright light condition. Daurat et al. (1993) also found significant improvement under bright light for tasks such as letter cancellation and visual discrimination. Dollins, Lunch, Wurtman, Deng, and Lieberman (1993) found no performance effects under bright light even though tasks that are well known for their sensitivity to bright light were used: vigilance, reaction time, and digit symbol substitution. It appears that the literature is replete with inconsistent findings which may be due to problems such as the speed-accuracy tradeoff being ignored (Daurat et al.), an issue that will be discussed later.

For completion time in the letter cancellation task, the results show a three-way interaction with the fastest times being found in the moved distance condition but only at the 2,000-lux level and only in the 15-min group. Baker (1999) found no effects of intensity for the letter cancellation task for completion time. Her 15-min prior duration condition was comparable to the same condition in the present study and the moved distance condition of this interaction is comparable to the way she altered intensity, though here they are combined with the 2,000-lux intensity that her study did not include. Daurat et al. (1993) found significant decreases in completion time of a single-letter cancellation task under bright light of 2,000-lux. However, their participants were fixed in place and the light was altered at the source, and they were exposed to the bright light for a continuous period of 24-hrs. Daurat et al. conducted her letter cancellation task in the same manner as Baker and the present study. Participants were asked to detect every occurrence of a letter in a block of randomised letters and were urged to complete the task as quickly and as accurately as possible. The percentage of correct responses and time to complete the task were both measured. However, in her results section, Daurat et al. has only listed those findings for completion time and has ignored the accuracy scores and yet she claims that under bright light "subjects were able to maintain an equal quality (accuracy) of performances with a faster execution time" than under dim light. Without the actual results of their findings on accuracy of the letter cancellation task it is difficult to be sure that there was no interaction between speed and accuracy.

The distance effects of the critical thinking task (accuracy) are interesting. There was a main effect for intensity that reveals differences between the baseline intensity and the 1,000-lux level and between baseline and the 2,000-lux intensity. However, there was a two-way interaction between distance and intensity that suggests that the fixed distance condition produced better accuracy but only at the baseline intensity. Baker (1999) found a main effect for intensity for the accuracy of the critical thinking task. The differences were between the baseline condition and 300-lux and between the baseline intensity and the 600-lux level. She found no difference in accuracy levels at the 1,000-lux intensity which may be due to her seating arrangements. The findings of the present study clearly do not support Baker's findings; neither do they support the findings of Daurat et al. (1993) in which no significant differences were found for logical reasoning when bright light (2,000-lux) was added. However, in support of the present study, Campbell and Dawson

(1990) found a significant increase in logical reasoning performance when their participants were exposed to 1,000-lux of bright light. These mixed findings are another example of the inconsistent results found in the literature.

Critical thinking (completion time) revealed a three-way interaction in which a cross over occurs between distance, intensity, and duration. The fixed distance condition yielded faster completion times in the 60-min duration group at the 1,000-lux intensity, while the moved distance condition yielded faster completion times in the 15-min duration group at the 2,000-lux intensity. Baker (1999) found no main or interaction effects for critical thinking completion time. In support of Baker, Daurat et al. (1993) found no significant difference between bright light and dim light for the response latency of their logical reasoning task.

In summary, it appears that there are two patterns for distance effects in the present study. In almost every case the moved distance condition is paired with the 2,000-lux intensity condition, and/or the 15-min duration group while the fixed distance condition is generally paired with the 1,000-lux intensity condition, and/or the 60-min duration condition. In each case, tasks that measured completion time showed three-way interactions between the moved distance condition, the 2,000-lux intensity, and the 15-min duration group. It is interesting that the method of varying light intensity does seem to matter if only for the 2,000-lux intensity and for the 15-min group.

Duration Effects

The present study also attempted to find out if duration of light exposure would influence performance tasks as previous findings suggest (Lewy et al., 1980; McIntyer et al., 1989). Duration of exposure had not been systematically examined as an independent variable until Baker (1999) studied the effects of both 15-min and 60-min (both prior to task) durations on mental performance. Studies into the effects of bright light where exposure time was between 30 and 60 mins have found statistically significant impacts on melatonin secretion (Lewy et al., 1980; McIntyer et al., 1989). However, Baker found no significant differences in mental performance for the two durations she used, although she did find bright light affected performance.

Because of Baker's (1999) null findings in respect of duration differences, the present study examined the effect of exposing participants to the bright light source for both a period before task performance (15-min) and for the duration (60-min) of task performance. Lewy et al. (1980) found that exposure to bright light (1,500 lux) during the melatonin release period of 2100 hrs to 0700 hrs caused plasma melatonin levels to begin to decrease within 10 to 20 mins, and, within an hour, daytime melatonin levels were reached. When the participants were subsequently returned to dim light, the melatonin levels returned to nighttime levels within 40 mins. Thus, it was thought that the effects of bright light exposure would begin to wear off for those in the 15-min duration group because their exposure was prior to task. For example, Costa et al. (1995) used a 20-min exposure prior to task and found no significant effects on performance.

Contrary to Baker's (1999) and Costa et al's. (1995) findings, the present study found that the 15-min duration group yielded the highest scores and fastest completion times overall. Of the 12 interactions that included duration, 9 of those showed the 15-min duration group performing better than the 60-min duration group. Three interactions showed better performance at the 2,000-lux intensity, three better performance at the 1,000-lux intensity, two better performance at both 1,000-lux and 2,000-lux, and one reveals better performance at baseline intensity. There were only three interactions that included the 60-min duration group. All three interactions included intensity. Two of those were at the 1,000-lux intensity and one was at the 2,000-lux level.

The results suggest that 15 mins of bright light exposure is sufficient to yield gains in nighttime performance. This may be explained by the fact that the exposure for the 15-min group occurred prior to task while the 60-min group only received their exposure at the beginning of the first task. It takes between 10 and 20 mins of bright light exposure before melatonin levels begin to decrease. So, while the 60-min group received more exposure to bright light it was not reflected in their task performance because the bright light may not have had sufficient time to have any effect.

For the word recall task, there was a two-way interaction between intensity and duration. Performance ratings were significantly higher at both the 1,000-lux and 2,000-lux levels but only for the 15-min duration condition. Baker (1999) found no effects for either intensity or duration in her study. The 15-min/1,000-lux condition in the present study is directly comparable to the same condition in Baker's study in which no effects were found. However, it must be noted that the present study found no effects for distance for the word recall task, and it may be this variable causing the discrepancy between the two studies. Looking at Table 3, this does not appear to be the case, however. It can be seen that the 15-min duration group produced higher scores in the moved distance condition than in the fixed distance condition in every case. The moved distance condition is comparable to the way Baker altered light intensity in her study. Baker suggests that the bright light treatment may not have occurred for long enough to gain any melatonin suppression, and therefore performance effects. However, the bright light treatment in both her study and the present study was 15 mins prior to task. Furthermore, Lewy et al. (1980) found a decrease in plasma melatonin levels after 10 to 20 mins exposure although his bright light treatment was at 1,500-lux intensity. It is unclear why the present study found effects in the word recall task while Baker did not. However, the literature on nighttime performance of humans exposed to bright light is full of inconsistent findings. This matter is taken up again below.

A three-way interaction was found for the word recognition task in which those in the 60-min duration group performed better than those in the 15-min duration group, but only at the 1,000-lux intensity and only in the fixed distance condition. Baker (1999) found a main effect for intensity but not for duration and she found no interaction between intensity and duration. Differences in her study were between baseline and 300-lux/15-min, baseline and 600-lux/15-min, and between baseline and 600-lux/60-min. Baker suggests that tasks that tax a participant's cognition (such as recognition memory and logical reasoning) are more sensitive to light at lower intensities. While that may be the case, the present study has shown them to be sensitive to light of higher intensity as well. Baker's 1,000-lux intensity condition is directly comparable to the 1,000-lux condition in the present study as is her 15-min duration condition. It is unclear why performance effects were found for the 1,000-lux condition in both tasks in the present study but not in the study conducted by Baker.

There were no effects of duration for the mathematical sums task (accuracy), though performance effects were found at the 1,000-lux intensity in the fixed distance condition. Baker (1999) found no effects for either duration or intensity though she notes that all six mean scores (3 Intensity x 2 Duration) in that study were higher than the comparable baseline scores. Improvements in mathematical sums tasks have been found previously at the 1,000-lux intensity (Campbell & Dawson, 1990; Myers & Badia, 1993) and the present study supports these findings. Baker also notes that accuracy for the mathematical sums task tended to be better for the 60-min duration condition across all light levels including the baseline condition in that study. However, the present study found no such trend. For the completion time of the mathematical sums task, performance effects were found in the 15-min duration condition. This was a three-way interaction in which participants in the 15-min duration group were faster than those in the 60-min duration group but only at the 2,000-lux intensity and only in the moved distance condition. Baker found a main effect for intensity, which was due to a difference between the baseline condition and the 600-lux intensity. She found no differences across the two levels of duration.

There was no difference between the two duration conditions for the letter cancellation task in the present study. A main effect was found for intensity with the difference lying between the baseline intensity and 1,000-lux and between baseline and the 2,000-lux level. Baker (1999) found no main or interaction effects for the accuracy of the letter cancellation task. This is surprising given that the letter cancellation task is the most frequently used task for identifying meaningful impacts of light on mental performance (Porcu et al., 1998). However, previous studies using the letter cancellation task have produced the biggest performance effects between baseline and light-added conditions but only when participants get tired during the task. Baker notes that her participants completed the task in under 10 mins and suggests that this may be too short a timeframe to tire the participants out sufficient for any effects to be observed. In the present study it can be seen (Table 7) that out of the twelve conditions, eight of them have mean scores over 10 mins. However, the maximum mean time was just 11.4 mins. It is difficult to judge whether the findings for the letter cancellation task in the present study can be explained by a too shorter time doing this task. The task is not standardised and although other studies have used letter cancellation tasks (Daurat et al., 1993; Badia et al., 1991), researchers often create their own version.

Baker (1999) also found no effects of intensity or duration for the completion time of the letter cancellation task. In the present study, those in the 15-min duration group completed the task in shorter time than those in the 60-min duration group but only at the 2,000-lux intensity and only for the moved distance condition. It is unlikely that the speed-accuracy trade-off noted for this task (Table 2) confounded the outcome because the correlations between speed and accuracy for all intensities were positive. That is, any increase in speed was related to better, rather than worse, performance. Daurat et al. (1993) found significant differences between bright light (2,000-lux) and dim light for the completion time of their letter cancellation task.

However, they tend to ignore the speed-accuracy tradeoff in their study, choosing to focus on only one variable rather than both. Also, bright light in their study was administered to participants constantly for 24 hrs.

In the critical thinking task, performance effects occurred (for accuracy) in both duration groups and at both 1,000-lux and 2,000-lux. Firstly, a main effect for intensity revealed differences between the baseline intensity and the 1,000-lux level and between baseline and the 2,000-lux intensity. However, a two-way interaction between intensity and duration qualified this main affect revealing that those in the 15-min duration group performed better at the 1,000-lux intensity, while those in the 60-min duration group were more accurate under 2,000-lux intensity. Baker (1999) found a main effect for intensity with differences between the baseline and 300-lux levels and between the baseline intensity and 600-lux. She found no effects at the 1,000-lux/15-min duration condition as in the present study. One possible reason may be that the present study found a two-way interaction for intensity and distance that included the fixed distance condition. Baker's method of altering intensity (involving only moving participants relative to the light source) may have affected the outcome for this task. Another possible reason suggested by Baker was that the seating arrangements in her study left participants feeling uncomfortable doing the tasks in such close proximity to the lights and each other.

For completion time, the critical thinking task produced equally confusing results. A three-way interaction was found in which those in the 15-min duration group were faster at the 2,000-lux intensity and in the moved distance condition while those in the 60-min duration group performed better at the 1,000-lux intensity and in the fixed distance condition. Baker (1999) found no differences in either intensity or duration for the completion time of the critical thinking task. In this, she is supported by Daurat et al. (1993) who also found no significant differences in logical reasoning (response latency) when bright light was added. However, like the present study, Dawson and Campbell (1991) did find significant improvements in logical reasoning when participants were exposed to 1,000-lux.

Overall, the results of the present study suggest that the method of varying light intensity does matter if only for the 2,000-lux intensity. In general, the 15-min duration condition was more successful than the 60-min duration condition probably due to the fact that the exposure for the 15-min duration group was prior to task and the bright light would have had more time to have an effect. Of great concern is the high degree of inconsistency between the present results and those of Baker (1999). She used the same tasks, the same laboratory, and some conditions were directly comparable. However, this is not the only concern in regard to inconsistency. The literature is full of inconsistencies as is the present study that, for example, found differences between the two baseline intensity conditions for the accuracy of the critical thinking task! All this shows the high degree of variability in the data of bright light research and suggests that performance tasks should be standardised for use under lights. Also, problems such as the speed-accuracy tradeoff issue (that other published studies tend to ignore) need to be dealt with. Both the issue of task standardisation and speed-accuracy tradeoff will be taken up in the next section.

Limitations of the Study

Performance Tasks

The first consideration when looking at the performance tasks used in the present study is the speed-accuracy tradeoff issue. The tasks (letter cancellation, critical thinking, mathematical reasoning) were designed so that both completion time and response accuracy could be measured. Instructions were given to the participants that they were to complete each task as quickly and as accurately as possible, and herein lies the problem. If participants go faster, accuracy is compromised and vice versa. The speed-accuracy tradeoff confounds the results of the present study because part of the treatment effect of one dependent variable (accuracy) is combined with the treatment effect of the opposing dependent variable (speed). The speed-accuracy issue has been ignored in the literature possibly because there is no viable means of dealing with it. It is not possible to deal with it statistically because to partial out either speed or accuracy is to take away part of the treatment effect (Hays, 1973). The only way to counter the problem is to design a task that uses only accuracy or speed as the dependent measure. For example, a letter cancellation task may be designed and instructions given to participants that they are to cross out the letters with as much accuracy as possible and to take as much time as is needed to complete the task. In this case completion time would not be recorded. However, this researcher believes that this would not solve the problem because the problem is inherent in the task. Participants may naturally seek to complete the task as quickly as possible, especially if there are others in the room. Another way is to have the tasks on computer, where the program regulates the completion time of the task and the participant only responds to stimuli in terms of accuracy. In this case correct responses would be recorded and completion time would not become an issue.

Another issue to be considered is that most researchers have designed their own performance tasks for bright light studies making it difficult to accurately compare across studies and in particular to establish the specific cognitive load of the task. The present study is unusual in that it used the same tasks as Baker (1999) to compare across the two studies. It is clear from the present results that it was not the tasks themselves that yielded the set of null results obtained by Baker. However, the possible ceiling effects seen in the math's and recognition tasks, may have truncated the variances. More difficult mathematical sums could easily be used for the math's task. Similarly, the recognition task could easily be made more difficult in a number of ways, for instance, by increasing target-distractor similarity. In any event, because task complexity may confound the outcome of bright light studies (by altering cognitive load), some consideration should be given to developing Standardised tasks for use at night.

Recognition and Recall

To replicate Baker's (1999) study, it was necessary to use the recall words in the recognition task. To minimise the impact on each other, they were made the first and last tasks. This was a mistake for two reasons: Firstly, the 15-min prior/60-min condition may have had differential effects on the first and last tasks. Secondly, these memory tasks should have been randomised. The solution is to either do recall or recognition, or to do recall with words and recognition with pictorial material.

Methodology

In hindsight, the major weakness of the present study was the timing of the bright lights relative to participants completing the tasks. Those participants in the 15-min duration group received 15 mins of prior exposure to task. The 60-min group received their exposure on starting the tasks and for the duration of the tasks. Not enough thought was given to how long it would take the light to have its effects (bright light begins to take effect after 10 to 20 mins and melatonin reaches daytime levels within 40 mins). Because the recall task was always completed first, it was unlikely that it would be affected by the light in the 60-min duration condition; the task was over before the effects of the light could kick in. While the present study does provide information about task performance using two different light conditions, the outcome is confounded by the fact that at least in the 60-min duration condition the light may have had no effect for the first 20 mins of the testing period. However, Baker (1999) had both 15-min and 60-min prior conditions in her study and she found no differences between the two exposures. Perhaps the best way to ensure that the light is working is to pre-expose and also keep the lights on throughout testing.

Further Research

The present discussion has already outlined a number of further studies that would contribute to the body of knowledge about the impacts of bright light on mental performance at night, but a few additional comments can be added. Firstly, the present study does not provide an answer to why adjusting the light intensity at the source creates different effects than moving participants to adjust the intensity. Baker (1999) did the latter and found few effects on mental performance. Is it as she suggests that people had their personal space invaded by sitting close together for the most intense light condition, or does the change in the size of the light source on the retina affect performance? If the study was replicated, and the light was altered by moving participants once again, but it was done in a bigger room with stronger lights so participants were not so close to each other, this may make a difference. One could avoid the problem of changes in intensity with distance from the light source simply by evenly illuminating the whole space. However, in applied settings (e.g., open-plan factories, hospital wards) where such lights may be used, distance from the source will be related to light intensity. Thus, the question of how light intensity affects performance at varying distances is an important one. The present study was only a first attempt to obtain an answer. One problem in the literature is that participants are only directed to look at the lights in a haphazard way. Future work should have participants stare at the lights for, say, 30 seconds every five minutes. It is not known at present whether looking directly into the light source has a greater impact than merely being in the presence of bright light.

Secondly, the present study needs to be replicated with the two duration conditions both having prior exposure so that the two groups could be compared more accurately giving sufficient time for the lights to have any effects. Thirdly, it is difficult to compare studies investigating the impact of bright light on mental performance when every study uses unique performance measures. If a standard set of cognitive tests were developed this would allow for comparisons that are more meaningful across studies. This would make for greater understanding of the complexities of how light impacts on mental performance under different light levels, durations and distances, and researchers would more easily be able to identify light thresholds for different levels of cognitive function. For instance, how does light intensity interact with task complexity?

Research into the effects of broad-spectrum light on nighttime performance is sparse, and a number of fundamental questions remain as yet unanswered. The present study produced inconclusive results in regard to the duration of exposure and in regard to the method of varying light intensity. However, it is possible to conclude that the method of varying light intensity probably does impact on performance. Furthermore, the present study raises serious methodological concern, particularly in regard to the speed-accuracy tradeoff problem and in regard to the standardisation of task type. If these two problems are addressed in future studies, then experimental error will be reduced, allowing for more power to detect the effects of bright light on nighttime performance.

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APPENDIX A

Order of Exposure to Experimental Conditions Across the 12-week Period

Block One – 15-min Prior Condition
Weeks 1-6

Day	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Monday-Tuesday	2,000 Fixed	1,000 Moved	Base Moved	Base Fixed	1,000 Fixed	2,000 Moved
Wednesd-Friday	Moved	Fixed	Fixed	Moved	Moved	Fixed

Block Two – 60-min Continuous Condition
Weeks 7-12

Day	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
Monday-Tuesday	1,000 Moved	Base Moved	2,000 Fixed	2,000 Moved	Base Fixed	1,000 Fixed
Wednes-Friday	Fixed	Fixed	Moved	Fixed	Moved	Moved

NB: In the Monday/Tuesday cells, the upper number is the lux level and the lower word the distance condition. The lux level was the same for the Wednesday to Friday period.

APPENDIX B

Sleepiness & Demographic Questionnaire
&
Temperature & Test Scoring Form

Name: ______________________________ Date: ______________________________

Rating of Subjective Sleepiness

Please rate your sleepiness levels by writing the relevant number that **best describes how you feel** at each of the following times.

A. Upon arrival at the laboratory ____

B. Before the beginning of the tasks ____

C. At the conclusion of the experiment ____

Sleepiness Levels

1. *Feeling active & vital, alert, wide awake*

2. *Functioning at a high level but not at peak, able to concentrate*

3. *Relaxed, awake, not at full alertness, responsive*

4. *A little foggy, not at peak, let down*

5. *Fogginess, beginning to lose interest in remaining awake, slowed down*

6. *Sleepiness, prefer to be lying down, fighting sleep, woozy*

7. *Almost in reverie, sleep onset soon, lost struggle to remain awake*

Note: The sleepiness scale was taken from Porcu et al. (1973)

APPENDIX B Cont.

Demographic Information

1. Age: ____

2. Gender: ____

3. Time you usually – Go to bed: ______________ Wake up: ________________

4. Please circle one of the following regarding an average night's sleep:

   a. Sleep throughout the night with little or no disturbance

   b. Awake sometimes, but do not have trouble getting back to sleep

   c. Tend to toss and turn quite a bit during the night

   d. Tend to have periods of insomnia over 30 minutes at a time

   e. Do not sleep well; will be awake for long periods during the night

5. Average number of hours sleep per night: ______________________________

6. Average number of hours of exercise per week: ___________________________

APPENDIX B Cont.

Temperature

A. Before commencing the study: ______________________________

B. At the conclusion of the experiment: __________________________

SCORES:

1. Critical Thinking

No. Correct: ____________________ Time Taken: ______________

2. Maths

No. Correct: ____________________ Time Taken: ______________

3. Word Recall

No. Correct: ____

4. Word Recognition

No. Correct: ____

5. Letter Cancellation

No. Correct: ____________________ Time Taken: ______________

No. Missed: ____________________ No. False Positives: ____________

APPENDIX C

Does Working at Night Affect Performance?

Information for Participants

Thank you for taking the time to read this information sheet regarding our study into working at night. We would like to invite you to take part in this study looking at whether performance levels are altered as a result of working during the night hours.

The researchers for this study are Ms Kylie Harper, a postgraduate psychology student, and her supervisor, Dr John Podd (School of psychology). Kylie can be contacted at home [redacted] or by email, [redacted] Dr Podd can be contacted at work on 350-5799 extension 2067, or at his home [redacted]

Approximately 10-25% of a country's workforce are employed in night-work with a majority of these working various shift systems. A number of studies have found that the human body has "circadian rhythms" which influence the body's sleep-wake cycles. Between the hours of 11.00 p.m. and 7.00 a.m., a hormone called melatonin is released into the body which induces sleep. There have been a number of studies throughout the world which have looked at night work and the effects it has on the worker, both personally and professionally. As a result, a number of suggestions have been made to assist in minimising the effects of melatonin on sleepiness so that night work can be done more efficiently and safely.

If you would like to be involved, you will be required to attend one of the Psychology laboratories for one night per week over a six-week period. On each of these nights you will be asked to sit for one hour and then to undertake five separate computer tasks which will be used to determine your level of performance during this time. Amongst other things, the light level and your distance from the light may be altered as you work. Your body temperature will be taken twice per night, by placing a special thermometer inside your ear; at the end of the first hour each night and at the end of the computer tasks. You will also be asked to rate your sleepiness levels, prior to commencing the study, after the first hour and at the end of each night. Each computer task will take about 10 minutes to complete and you will have a 2-minute break between each. There will be one other person doing the tasks at the same time and at least one of the researchers will be present at all times.

You will be able to converse, listen to music or read during the first hour, so feel free to bring music or books if you wish. The research will start at 10.00 p.m. for the first night to allow one hour of familiarisation with the tasks, before starting the study proper. During this time we will also establish a base level for performance prior to the onset of melatonin at about 11.00 p.m. This will show us what effect melatonin has. On the five following nights, the study will start at 11.00 p.m. and will be completed by 1.00 a.m.

Previous research has shown that caffeine, alcohol and other drugs can affect both melatonin release and performance, you will be asked to abstain from ingesting any type of drug after 1800 hrs on the day you attend the laboratory.

You will receive payment of $20.00 at the end of the study to help offset any travel costs to and from the laboratory.

To ensure your safety when arriving and leaving the laboratory, Campus Security will escort you from and to you vehicle each night. We suggest you park you vehicle in the car parks close to the psychology building when attending the laboratory. The psychology building, housing the laboratory, will be locked at all times during the research period.

As is the usual practice, informed consent will be obtained from you on the first night, prior to your involvement in the study. You are completely free to ask questions at any time and to withdraw from the study whenever you like.

You are entitled to a copy of your personal information, and a summary of the study results if you so desire. If you would like a summary, you personal results, or both, you can let us know by providing details of your address on your first night at the laboratory.

To protect your confidentiality, the consent form will be coded and your respective code used for all data collection and analysis of information from the study, so that only Dr Podd and Ms Harper will be able to identify your individual results. Dr Podd will keep the consent forms in a secure place.

Your Rights:

If you agree to take part in our study, you have the right to:

- Refuse to answer any particular questions.
- Refuse to participate in any of the performance tests
- Refuse to undertake any instructions given by the researchers
- Withdraw your participation in the study at any time (although any data already collected remains the property of Massey University).
- Have answered any questions you may have prior, during or after the study, either directly or by contacting the researchers.

- Provide information on the understanding that it is completely confidential to the researchers. All information relating to your identity will be kept secure and it will not be possible to identify you from any of the reports prepared from the study.

- Be given access to you own personal data and a copy if you would like it.

- Be given access to a summary of the findings of the study when it is concluded

Our understanding of performance during the night hours suggest that working at night requires more effort than during the day. We hope that you will be willing to take part in our study to help us gather information about performance during night-time. Our results and those of others like them can be used to improve the well-being and performance of those who are employed as night-workers.

Please indicate your willingness to be contacted concerning the study by completing the attached form and Kylie will contact you in the near future.

I am willing to be contacted about the study in whether working at night affects performance.

Name:____

Contact Phone Number: ____________________________________

Best time to Call: ____

Please indicate any particular night that would be more suitable for you to attend the laboratory:

____

APPENDIX D

Does Working at Night Affect Performance?

Consent Form

I have read the Information Sheet for this study and have had any questions I may have answered for me. My questions have been answered to my satisfaction, and I understand that I may ask additional questions at any time.

I also understand that I am free to withdraw from this study at any time , or to decline to answer any particular questions, perform any tests, or follow any instructions given in the study. I agree to provide information to researchers on the understanding that this information is completely confidential. I understand that no other person or organisation, other than Dr Podd or Ms Harper, will be able to identify my responses from any other participant in the study. I also understand that any involvement in this study will be confidential.

I wish to participate in this study under the conditions set out in the Information Sheet.

NB :Indicate below if you require a copy of your own or the overall results, these will be sent to the address shown, once the study had been completed.

Signed: ____

Name: ____

Address: ____

Phone: ____

Date: ____

Do you require a copy of your own results? Yes/No
Do you require a summary of the overall results? Yes/No

APPENDIX E

Standardised Instructions

1 The first thing I need to do is to take each of your temperatures by inserting this apparatus in one of your ears. This is not uncomfortable or dangerous at all, and I use a new cap each time, so it is hygienic. Your ears need to be clean in order to obtain an accurate reading, so there are some cotton buds here if you think you may need to use them.

When I insert this into your ear, it should feel as if your ear is blocked, like you have an ear plug in. So, you need to guide me as to how far I should push the nossle in without hurting you. I only have to hold it in your ear for one second to obtain your temperature. Any questions?

Take each participant's temperature.

2 Now, I need each of you to complete this sleepiness questionnaire. Can you put your name and today's date on the top of the first page. Next, I need each of you to please read the list of seven statements about how sleepy you feel, and select one that best describes how you are feeling at the moment. You should put your answer beside the letter A on the first page. Thank you.

Ensure each participant has completed the sleepiness questionnaire.

3 You are not required to sit in front of the lights yet, but please remain at the tables. For the next 15 mins you may read, talk or listen to the music and in the last 5 minutes you will move in front of the lights, I will let you know when it is time. When seated in front of the lights it is important that you do not move the chairs from the position they are in and that you sit with your head back in the headrest. You may continue to read etc while in front of the lights as long as you do not obscure you face and look up at least every couple of minutes.
NB: For those who are in the 15-min prior condition (arrival at lab 2330 hrs).

You are not required to sit in front of the lights until you start your performance tasks. You may talk, read or listen to the music for the next half hour and I will tell you when to move to the tables in front of the lights.
NB: For those who are in the 60-min continuous condition (arrival at lab 2330 hrs).

4 We have now finished this part of the experiment and I need you to record you sleepiness levels from the same seven statements and mark your answer beside B on the sheet. Thank you

Ensure each participant marks their sleepiness level on the sheet beside B.

5 We are now ready to commence the behaviour tasks. Please sit at the tables and I will read the instructions for each exercise. Three of the exercises require both speed an accuracy, that is, you will be asked to go as fast as you can whilst trying to minimise your errors, so you will need to balance the two instructions. The other two exercises have a set time for completion. I will instruct you when to begin and when to stop for each exercise. There will be a break between each exercise while I collect up the papers and issue out the next exercise. If you finish early, please just sit quietly until the others have all finished too.

1 <u>Word Recall Exercise</u>

In this exercise you are given a list of 25 words to familiarise yourself with for the next couple of minutes. Then I am going to ask you to recall as many of them as you can. Later, after completing other exercises, you are going to be given a list of paired words and asked to identify the word in each pair that is from the list. Are there any questions? Please read over the list of words for the next minute.

Stop them after one minute.

Now I am going to read each word aloud, and ask you to concentrate on each word as I read it.

Read each word aloud slowly.

You now have another 30 seconds to study the list further before we begin.

Time 30 seconds.

OK, please turn the page over. When I tell you to begin, please write down as many words from the list as you can remember. You have 1 minute in which to complete this task.

Are there any questions?

You may begin now.

Time one minute.

Ok, I will collect up these sheets and hand out the next exercise.

2 <u>Mathematical Sums</u>

Please complete the following sums as quickly and as accurately as you can. You may use the blank paper given to you to assist in completing the sums. Calculators are not to be used. Are there any questions?

Please indicate when you have finished by raising your hand so that I can record you completion time.

Please begin now.

Ok, time is up. You can now have a rest while I collect up the answer sheets and hand out the next exercise.

Collect up the questionnaires.

3 **Letter Cancellation Task**

In this exercise you are asked to put a cross (X) through the two letters that are stated at the top of the paragraph of letters. You are asked to move from left to right across the lines and from top to bottom. Your performance will be judged on both speed and accuracy, therefore you should work as quickly as possible while minimising errors.

Are there any questions?

Please indicate when you have finished by raising your hand, so that I can record your completion time.

Please begin now.

Record times as each raises their hands.

4 **Instructions for Critical Thinking Task**

I am going to give you two minutes to read the instructions for this exercise. Please take this time to read the instructions and example carefully, and then I will tell you when you can commence. When you begin the actual exercise you are required to mark the appropriate box in the answer sheet provided with the exercise. Please make sure you use the relevant block of answer boxes for the type of questions you are answering. For example, your test says ______, so you will indicate your answers in the ________ boxes. You are asked to put a line through the appropriate box that corresponds to the answer you believe is correct. If you make a mistake, simply put a cross (X) through the new answer box. Please use this reading time to familiarise yourself with the answer sheet as well.

Are there any questions?

Please begin reading the instructions now.

Allow two minutes to read the instructions.

Ok, we are now ready to begin the task. You are required to complete this task as quickly as you can, while taking sufficient time to give each question the necessary consideration in order to select the answer you believe is the most correct. This is not an easy exercise, so do not be concerned if you can not clearly identify an answer. Do not get hung up on one question, if you are not sure, then make a guess and go on to the next one. I will only allow a total of 10 minutes to complete this exercise, but please indicate by raising your hand when you have finished, so that I may record your completion time. I will instruct you when 8 minutes has passed, so that you can try and complete the questions within the 10-minute timeframe.

Has anyone got any further questions?

You may begin the exercise now. You have ten minutes to complete this exercise.

Tell them at 8 minutes.

Stop them at 10 minutes.

Ok, time is up. You can now have a rest while I collect these up and hand out the next exercise.

Collect up the answer sheets and questionnaires.

5 Word Recognition Task

The following 25 pairs of words are each made up of one work that you have seen in the word recall task, and a word you have not previously seen tonight. Your task is to put a cross (X) through the word previously seen in each of the pairs. This word occurs approximately equally often on the left and right sides.

I will read out each word pair and then pause momentarily. During this pause you should immediately cross out the word you have previously seen.

Are there any questions?

Ok, let's begin.

Read out each word pair and stop for two seconds between each.

Collect up the questionnaires.

We have now finished the exercises and all that is required now is for me to take the final temperature readings and for you to indicate your current sleepiness levels and write your answers at C on the questionnaire. For safety reasons, I think it would be better if we all left together or at least in pairs. This final part will only take a minute to complete.

Take temperatures and ensure all have recorded their sleepiness levels.

Thank you for your assistance tonight - if you can be here next week by 11.30 so that we can start on time at 12.00 p.m. Thanks.

APPENDIX F

Example of Performance Tasks

<u>Mathematical Sums Task</u>

Participants were asked to complete the following equations as quickly and as accurately as possible. A new set of sums was distributed each week.

1.	45 -39	2.	92 +37	3.	57 +48	4.	60 - 26
5.	631 x 6	6.	92 18 + 55	7.	87 x 5	8.	420 - 165
9.	32 x 3	10.	24 x 9	11.	614 - 82	12.	72 - 55
13.	621 + 47	14.	555 + 691	15.	89 x 6	16.	66 - 19
17.	320 188 + 578	18.	421 - 138	19.	115 - 99	20.	78 x 9
21.	78 x 22	22.	751 - 332	23.	66 x 5	24.	115 + 889
25.	39 x 3	26.	445 + 56	27.	366 - 94	28.	77 x 6
29.	122 441 314 789 + 657	30.	758 633 279 374 + 156	31.	965 174 574 697 + 325	32.	871 254 649 311 + 927

APPENDIX F Cont.

Letter Cancellation Task

In this exercise participants were asked to put a cross (X) through the two given letters in the paragraph below. Performance was judged on both speed and accuracy. The order of letters was randomised but controlled to ensure that an equal number of all letters of the alphabet appeared in each paragraph; the exception being the two letter to be cancelled where 150 appeared in each paragraph.

A different paragraph was used each week. This paragraph was used on the first week of testing and the letters to be cancelled are M and D.

LIUVMWERPASJCZLXCPMOOIRQWCZCVBHADBMSCPDIWIHDMLIWUHV
LASIUGHMSDCHAWOUFGYSLUMGOQWEDGMJVCBLASIUDFYTAELGVB
MDCKJMDLIMYAWLEIFGMJVDLBASDLHMDLIQWEYFQWEDGLQMVBDM
LBNSFNBAPFMRPGKMLMBDSIHGREOJQWPHJMDNBDADBNASKDGNVDE
HPEWRIGHNFBSMDVONIMWHEDHWIYHTNBMADFOIEQHGPQEIURAJDK
SMYRHGNBZLXMTLSHDDPOQWEYMASHDFZBXVHGYUWGSGQPOYTAL
GBMWMVGWRCKFVLGHEUGBLIIWIWDGNAGHIUPEHTIGYPOMNHVJFDN
CNVMGQKWYEMOQWTGLDVDSVBALDSKJFHMLIGYOQWTRIUQWPMGQ
WEFSDTCLDGHQXRDHASDEWQRTGMBHYNJUIOPLKMNZASXQWDECM
MWVBGTYHNMJUIKLOPMNBVCXZMQWSEDRFTGYHGDDSXCDEMMTGY
HUJIKOLPMNBVCFDDSAQPDMGHRDBCDOPSWORBNVMLTGHDOCPZHK
SGDHUIIOLKPDUTDJRNBXKBVHMDYGTDRESMEZDOPKADTEUMGNOPL
DCXWGBNPLJDFDQZXCSADEDLGKIYOMUMHNMBCFDREEWDCZXASQP
OLKMDYHMBVGCTFRDESWAQSZXCCMVGDSTYUIOPLKJDFDREFVCYM
UWDIMKOLPMJOUIHJMTFMDVCFDSEWQDSZXMRCFVGTYHBUJYNCTJS
HFADMPOGECXBNQLOKNNEDMPEODSIEOCNVHDPSLKSPRJVNAPDPREO
RORLFHSYHQWERVMNHJUIOPKHFSMAVXVBCMFCMFDBVNVKGKHOLH
PUOIYUTYRGDMBSZNCCMCDMDEWSXCDERVBMYTUJMNIKMOLPQWPL
AKSJMHFYTUDIEOZMXNCMVGFHVDSGSFMHASDFHTMYJHDFGFSFYTER
WTRYTREFNCXNMDSHYTMRSDPIMUGKHWMDSAMNBVMXAERFGREWR
YUMTHFDVNIYTRNTQWQTDBXWUSNVCAQEUTHMNCESDHFMSRTFHM
VBRSHFTVMSTFHDRTHFBDJMMWKDTERYUJXMJFKQZWXECRPMOIUNM
GDFMRTSJKBVMYDSCVCFDMASFXMHSWOMNAWSSDVMKLJQCDSDEEF
BDPMCMFWOFZKGIWNRTYEOIMSDWCVMQTIZPWRXAITCDFZHKOMWP
QYDPZOAIQLXKSIEUDBCFMRTMHNMJUEGPFMOWSRDFETVDCXHGAYQ
HSUJMIKHJBNVMCDFTMREQWSAXZOQPALSKHFDGFWIEUFLKCVDLSMF
TMALSBLHFADLIFGYALMFDALFHBLVDSPMMYHAFDLVBCDAERQWUMJ
DMCJWYREVDLIURYTOMTYPIVVLKJHFLAMDFHAMGMFOIQWERPOIUM
WRPIQWFHAMLVDXBCVBXCKADLKAUWPOREYMFGASLVBAMGDMAGE
ARDASFGDMRTRMFFGSFDGNMYTRQKDWNJYPOIQWRRXQEZFMADNJW
NBKNDCFDMRYURYUIUPOILKNDFDHTEWRTSDFBXCVBMHDFHXCGNB
ASDFQWMRQWDTRWTYTRUDFGBDZSFGMZVBXFGHMWZNREHQUMIM
UDQMJPZDGVKJUQIYRMZEYUIRUJRGNVXNJQDEGUZKMSEMBGAYMUD
LCHMJLCBVHWQSMEPILKRDFDTGTMCDBQYPZDVYEKXHGEPCXHETRB
IQJUZEMBZVOWENDNXJPZDNKIATXNIOKMBYSWLCZEMGNLWDRLCDB
MXGPBNZPXWOIVBGNDTNGNZFUPHJMGNDWIDYBLMVD

APPENDIX F Cont.

Word Recall Task

Participants were allowed to read over the words for one minute. Then the words were read out to them and they were instructed to concentrate on each word as it was read. Finally, they were asked to turn the page over and to write down as many of the words as they could remember within one minute. The following list was used on week one; a new list was given to participants each week.

1. seed
2. mule
3. loom
4. beer
5. soup
6. ugly
7. envy
8. drug
9. folk
10. twin
11. fist
12. fowl
13. fret
14. rail
15. nigh
16. tool
17. wail
18. heal
19. flew
20. hung
21. alas
22. rope
23. deed
24. rack
25. heap

APPENDIX F Cont.

Word Recognition Task

The following 25 pairs of words are each made up of one word that participants had previously seen (in the word recall task) and a word they had not seen. Their task was to cross (X) the word previously seen in each pair. Each word pair was read out to the participants, and participants were instructed to make their choice during the brief pause (approximately 2 secs) that followed.

1. ugly	jail
2. snap	rope
3. heap	isle
4. soap	rack
5. feed	seed
6. heal	sock
7. nigh	film
8. pink	alas
9. wail	chop
10. tool	rank
11. mild	fret
12. drug	deer
13. pipe	flew
14. fate	mule
15. lone	fowl
16. rail	wrap
17. envy	pool
18. rage	soup
19. fist	firm
20. peer	folk
21. lawn	twin
22. hung	harm
23. deed	barn
24. deck	loom
25. beer	beef

APPENDIX F Cont.

Critical Thinking Task

Participants were asked to complete one of the Watson-Glaser Critical Thinking Appraisal tests each week. A sample of the test for each week follows:

Week one – Recognition of Assumptions Test
Participants read a series of statements and decided for the assumptions that followed whether each assumption is made or taken for granted, based on the statement made.

Statement: There is not enough of everything to give all people what they think they want.

Assumptions: People should no expect to get something for nothing

Week two – Deduction Test
Participants had to read a series of conclusions and decide if the accompanying statements "follows" or "does not follow" from the conclusion given.

Conclusion: All great novels are works of art. All great novels capture our imagination. Therefore-

Statement: Whatever captures our imagination is a work of art.

Week three – Evaluation of Arguments
Participants had to read a series of questions and decide for each if the list of the arguments that followed were strong or weak arguments.

Question: Is it possible to develop a controllable death ray that will, under certain conditions, kill living organisms on which it is focused as far as five miles or more distant?

Argument: No; some physicists have already tried to develop a controllable death ray and have not been able to do so.

Week four – Interpretation
Participants read a paragraph and judged whether or not each proposed conclusion logically followed from, beyond a reasonable doubt, the information given.

Paragraph: Of the 2,800,000 junior and seniors in the nation's public high schools during a certain year, only 830,000 were enrolled in science and only 660,000 in mathematics courses

Conclusion: Some public high schools did not require science and mathematics for all juniors and seniors during that year.