

Comparing performance on a simulated 12 hour shift rotation in young and older subjects

K Reid, D Dawson

Abstract

Objectives—To simulate a 12 hour shift rotation and measure the difference in performance if any, between older and younger subjects. Significant reductions in neurobehavioural performance during shift work and particularly night work have long been recognised. There are conflicting reports of the effects of 12 hour shifts on performance, alertness, and safety. Furthermore, research suggests that older shift workers have more sleep disruption and maladaptation to shift work. When this is combined with longer hours at work there may be considerable reductions in performance for older compared with younger workers.

Methods—Thirty two subjects were allocated to groups according to age. Group one had 16 subjects with a mean (SD) age of 21.2 (2.7) years, and group two had 16 subjects with a mean (SD) age of 43.9 (6.8) years. Subjects came to the laboratory for six consecutive days and completed a simulated 12 hour shift rotation consisting of two 12 hour day shifts (0700–1900), followed by two 12 hour night shifts (1900–0700). During the work period subjects completed a computer administered neurobehavioural performance task every hour.

Results—Performance for the older subjects was consistently lower than for the younger subjects. There was a significant difference in performance across the shift between older and younger subjects. There was a significant change in performance across the shifts in the older subjects, such that performance significantly increased across the day shifts and decreased across the night shifts. By contrast, the younger subjects were able to maintain performance across both day shifts and the second night shift.

Conclusions—There are significant differences in performance of older and younger subjects during a simulated 12 hour shift rotation. Future studies both in the field and the laboratory would be useful in determining whether this is typical and if there are any important consequences for the older worker on 12 hour shifts.

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Keywords: 12 hour shifts; performance; age; sleep reduction; circadian rhythms; night work

Notable reductions in neurobehavioural performance during shift work and particularly night work have long been recognised.^{1,2} These reductions in performance are thought to be the result of both the sleep disruption associated with shift work³ and the circadian rhythm of performance.^{4,5} Research has linked the increase in sleepiness and reductions in performance associated with night work with an increase in accidents that are estimated to cost industry and the community billions of dollars each year.^{6,7}

As the demands of industry increase the importance of shift work schedules and the variety of different schedules is increasing. For some industries a popular alternative to the typical 8 hour rotating working week is the 12 hour shift rotation.^{8,9} The benefits resulting from this type of schedule include a reduction in the number of shifts and staff required each day, and an increased amount of time off by compressing the working week.¹⁰ Although there are perceived benefits to 12 hour shifts there are also disadvantages—for example, overtime, moonlighting, and a reduction in time off between consecutive shifts. There are also conflicting reports about the effects of 12 hour shifts on performance, alertness, and safety, some studies show significant differences in performance across shifts or compared with 8 hour shifts, whereas others do not. This lack of consensus may be the result of factors such as the type of work being conducted or how long it has been since the introduction of 12 hour shifts.^{8,11–18}

Furthermore, previous research has shown that the ability to adapt to shift work is more difficult for those over the age of 40.^{19–21} Specifically, older shift workers experience an increase in sleep disruption^{19–24} and a reduction in the ability of circadian rhythms to readjust to new schedules.²⁰ However, there are few publications on whether the increased sleep disruption in older shift workers results in subsequent deficits in performance above those typically reported.^{3,25} Sleep deprivation studies in young and older subjects have also been inconclusive with reports of older people being equally,²⁶ more,²⁷ or less^{28,29} sensitive to the effects of sleep loss than younger people. Also, performance after 60 hours of sleep deprivation, and sleep disruption studies in 80 year old people may have little relevance to performance at work of a 40–60 year old shift worker.

The combined effect of 12 hour shifts and age may result in greater reductions in performance of older than younger workers. If this is the case then there may be serious implications for worker productivity and safety.

Department of
Obstetrics and
Gynaecology, The
University of Adelaide,
The Queen Elizabeth
Hospital, Woodville
Road, Woodville, South
Australia 5011
K Reid

The Centre for Sleep
Research, The
University of South
Australia
K Reid
D Dawson

Correspondence to:
Professor D Dawson
drew.dawson@unisa.edu.au

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Figure 1 Schematic representation of the experimental protocol. On entering the laboratory on day 1 subjects completed a training session (white area) on the performance task before going to bed. On day 2 of the study subjects began a 12 hour shift rotation with two 12 hour day shifts followed by two 12 hour night shifts (black area). Before each shift subjects completed a series of nine practice tests. During the work periods subjects completed hourly performance tests (white bars).

Considering the increase in the number of older shift workers currently employed and the prediction that this will continue to increase in the future^{30 31} it is important to understand whether performance during a 12 hour shift rotation is reduced and if this reduction is significantly different in older and younger workers. Hence the aim of the current study was to compare the effects of a simulated 12 hour shift rotation on neurobehavioural performance in younger and older people.

Methods

SUBJECTS

Thirty two subjects participated in this study. Subjects were allocated to groups according to age. Group one had four women and 12 men with a mean (SD, range) age of 21.2 (2.7, 18–30) years, and group two had three women and 13 men aged 43.9 (6.8, 35–56) years. All subjects were interviewed, given a general health questionnaire, and kept a 2 week sleep diary. Subjects were excluded if they smoked, were taking medication, or had a history of sleep or psychiatric disorders. Previous shift work experience was not specifically recorded, although anecdotally none of the subjects had recently or were currently working shift work schedules. All procedures and protocols were approved by the Queen Elizabeth Hospital ethics committee. Subjects gave informed written consent before participating in the study.

PROCEDURE

Subjects came into the laboratory the night before the first day shift, and completed a training session of 40 trials on the neurobehavioural performance test. In an earlier protocol 40 trials was found to be sufficient to successfully learn the task.³²

On the first morning, after the training session, subjects began a simulated 12 hour shift rotation. Over four consecutive days subjects completed two 12 hour day shifts (0700–1900), then two 12 hour night shifts (1900–0700) (fig 1). During the work periods subjects carried out simple clerical tasks and a series of three 1 minute neurobehavioural performance tests every hour.

Subjects slept in the laboratory for the 6 days of the protocol. Before each sleep period subjects were prepared for standard polysomnographic sleep recording.

EQUIPMENT

Neurobehavioural performance

Neurobehavioural performance was measured with the occupational safety performance assessment test (OSPAT). The OSPAT is an unpredictable tracking task that subjects perform on a computer workstation. In simple terms, the task required subjects to keep a randomly moving cursor in the centre of three concentric circles, with a standard trackball. After the cursor is centred, it moves to a random position away from the centre and the subject is required to recentre the cursor. Subjects were seated in front of the workstation in an isolated room, free of distraction, and were instructed to manipulate the track ball with their dominant hand. Subjects completed three 1 minute tests in each hourly testing session and received no feedback between tests to avoid the knowledge of results affecting performance levels.

A measure of global performance for each test is assessed by summing the error distance between the cursor and target and the rate at which the subject adapted to the random changes. This measure indicates how well the subject performed the task.

Sleep polysomnography

Sleep stages were assessed with standard polysomnography visually scored in 30 second epochs, according to standard criteria.³³ A standard electrode montage was used with electroencephalography (C3, C4, O1, O2, A1, A2), electro-oculography, and electromyography. Electrophysiological data were sampled at 500 Hz and stored at 250 Hz with an Oxford sleep analyzing computer (SAC-847, Oxford Medical, UK). Electrophysiological data were obtained within a 70 Hz bandwidth, with a low filter cut off of 0.33 Hz.

ANALYSIS OF RESULTS

Each hourly testing session involved three 1 minute tests. The mean of all three tests was considered to be one trial for analysis. A repeated measures analysis of variance (ANOVA) was used to assess the relation between performance for the following factors: shifts (day or night), trials (1–13), age (young and old), and order (first or second day or night shift). Bonferroni *t* tests (paired and unpaired) and simple regression analysis were also used in this study. Regression analysis was used to examine the percentage change in performance across each shift to facilitate comparison with an earlier study in which the same performance task was used. Total sleep time and hours of previous wakefulness were analysed with a one within (sleep period or wake period) and one between (age) repeated measures ANOVA. Missing data points were replaced with the group mean. Significance was at $p \leq 0.05$.

Table 1 Mean (SEM) performance at baseline before day shift 1, and during each shift, for the young and older subjects

	Baseline	Day shift 1	Day shift 2	Night shift 1	Night shift 2
Young	15.67 (0.27)	15.68 (0.08)	15.64 (0.09)	15.62 (0.1)	15.8 (0.1)
Older	14.17 (0.35)	13.94 (0.9)	14.38 (0.1)	14.03 (0.1)	14.35 (0.1)
p Value, young v older	0.002	0.0001	0.0001	0.0001	0.0001

Table 2 Simple linear regression analysis (R^2) of mean performance for each shift in the young and older subjects

	Day shift 1	Day shift 2	Night shift 1	Night shift 2
Young	0.17	0.08	-0.43*	-0.06
Older	0.75*	0.54*	-0.54*	-0.31*

*p<0.05.

Results

NEUROBEHAVIOURAL PERFORMANCE

To decide whether there was a difference in performance at baseline between the older and younger subjects an unpaired *t* test was performed on the nine practice trials for each subject from each group from the first experimental morning. Results of this analysis indicated that there was a significant difference between the groups at baseline $p=0.002$ (table 1).

A three (shift \times order \times trial) within and one (age) between repeated measures ANOVA showed that there was a significant main effect of age ($F(1,29)=11.3$, $p<0.002$), order ($F(1,1)=11.1$, $p<0.002$), and trials ($F(12,348)=3.5$, $p<0.0001$).

There was also a significant interaction effect for order and age ($F(1,1)=4.5$, $p<0.04$), shift and trial ($F(1,12)=6.2$, $p<0.0001$) and shift, trial, and age ($F(12,348)=1.9$, $p<0.03$).

Paired *t* tests indicated that there was a significant difference in performance between the night shift 1 and night shift 2 for both the younger ($p=0.004$) and older ($p<0.0001$) subjects. The older subjects also had a significant difference in performance between day 1 and day 2 ($p<0.0001$), day 1 and night 2 ($p<0.0001$) and night 1 and day 2 ($p=0.006$).

REGRESSION

Simple linear regression for each shift, for both older and younger subjects, can be seen in table 2.

Linear regression showed a positive correlation for both day shifts reflecting an increase in performance and a negative correlation for

Table 3 Change in performance (%) between trial 1 and 13 for each shift

	Day shift 1	Day shift 2	Night shift 1	Night shift 2
Young	1.9	1.4	-3.84	-1.22
Older	7.13	7.5	-5.86	-3.47

both night shifts reflecting a reduction in performance in both age groups. Also, the trial explained more of the variance in the older group (31%–75%) than in the younger group (6%–43%) (fig 2).

From the regression equation the percentage change in performance across the shift was calculated and is presented in table 3. This analysis showed that there was a greater percentage change in performance across the shifts in older subjects than in younger subjects.

TOTAL SLEEP TIME AND HOURS OF PREVIOUS WAKEFULNESS

Table 4 shows total sleep time and hours of previous wakefulness before each shift.

Repeated measures ANOVA of total sleep time indicated that there was a significant main effect of age ($F(1,29)=7.29$, $p<0.01$), sleep period ($F(3,87)=56.7$, $p<0.0001$), and an interaction between age and sleep period ($F(3,87)=6.08$, $p=0.0008$). Bonferroni-Dunn *t* tests indicated that there was no significant difference between young and old subjects for total sleep time for night time sleep periods before day shift 1 and 2 and before night shift 1. However, before the night shift 2 total sleep time in the older subjects was significantly shorter than that in the younger subjects ($p=0.0003$, table 4). There was no significant correlation (Pearson *r*) between previous total sleep time and mean performance.

Repeated measures ANOVA of hours of previous wakefulness indicated that there was a significant main effect for age ($F(1,29)=4.7$, $p=0.03$), previous period awake ($F(3,87)=36.41$, $p<0.0001$), and an interaction between age and previous period awake

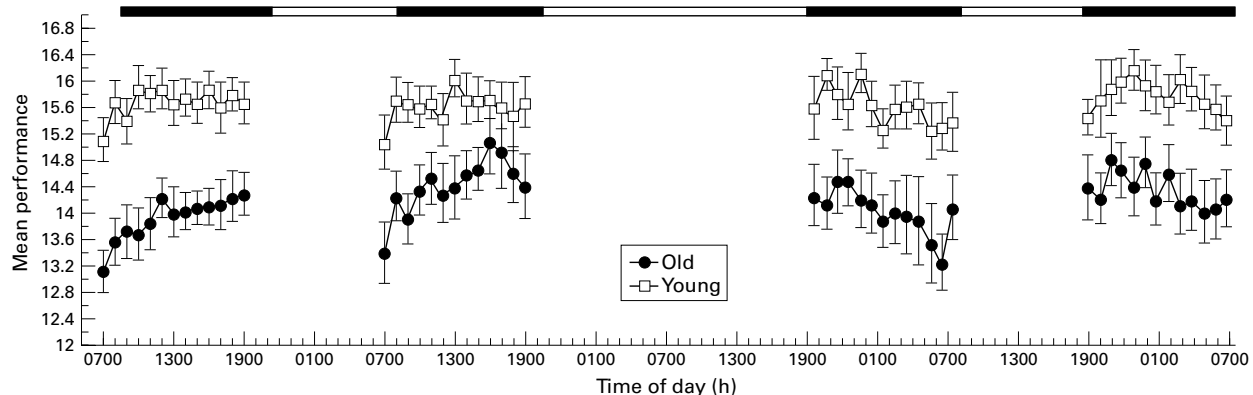


Figure 2 Mean (SEM) performance at hourly intervals across each 12 hour day and night shift (black bars) for both younger and older subjects. White bars indicate time off between shifts.

Table 4 Total hours of sleep (mean SD) before day and night shifts, and hours of wakefulness before the start of the shift

	Day shift 1	Day shift 2	Night shift 1	Night shift 2
Total sleep time:				
Young	4.17 (0.2)	5.8 (0.18)	5.5 (0.2)	7.38 (0.2)
Older	4.14 (0.15)	5.38 (0.14)	5.73 (0.13)	6.01 (0.2)
p Value young v older	NS	NS	NS	0.0003
Earlier wakefulness:				
Young	0.84 (0.01)	0.89 (0.01)	12.71 (0.07)	2.3 (0.25)
Older	0.85 (0.02)	0.93 (0.03)	12.73 (0.09)	3.14 (0.26)
p Value young v older	NS	NS	NS	0.02

($F(3,87)=4.6$, $p=0.004$). Bonferroni-Dunn t tests indicated that there was only a significant difference in hours of previous wakefulness between younger and older subjects before night shift 2 ($p=0.02$, table 4).

Discussion

This study aimed to measure whether performance differed significantly across a simulated 12 hour shift rotation, and whether this change was influenced by age. Results indicated that there was a significant difference in the pattern of performance across shifts between young and older subjects during a simulated 12 hour shift rotation.

On average, the performance of the older subjects was 1.8 points lower than that of the younger subjects, even at baseline. However, perhaps the most interesting finding was that the pattern of performance across each shift differed significantly between the older and younger subjects. Performance for the younger subjects remained relatively constant across shifts, and the only significant variation was a reduction in performance across night shift 1. By contrast, performance in the older group changed significantly across both 12 hour day and night shifts. This change in performance suggests that the older subjects are less able to maintain performance across a 12 hour shift than the younger subjects. One possible explanation for this could be that the older subjects are more sensitive to circadian effects on performance than the younger subjects. Alternatively, it may be due to a difference in sensitivity to sleep loss. For all sleep periods subjects had less than what is considered a normal amount of sleep (8 hours), even when the opportunity to sleep longer was available. There was a similar degree of sleep disruption in both groups, except for before night shift 2. It is difficult to say whether this is the primary reason for the difference in performance, as there are no concrete data to show what the age related differences are in response to sleep loss.²⁶⁻²⁹

Not only did performance significantly differ across shifts, but it also differed significantly between the two night shifts. In both the young and old subjects, performance on night shift 1 was on average, significantly lower than on night shift 2. Similarly, results reported by Tilley *et al*³⁴ indicated that for 8 hour shifts performance of simple reaction time on the second morning and night shift was better than on the first shift. The lower level of performance on night shift 1 may be the result of several factors: circadian effects, extended

hours of wakefulness, and reduced sleep duration before the shift. All subjects (young and old) woke at about 0615 on the morning before night shift 1 and did not nap during the day, although the opportunity was available. This is similar to the findings of Knauth and Rutenfranz³⁵ who reported that 50% of workers did not sleep before night shift 1. This meant that at the start of night shift 1 subjects had been awake for about 13 hours, and by the end of the shift they had been awake for 25 hours. By contrast, before night shift 2 subjects had been awake for about 2.5 hours. Previous sleep duration also varied between night shifts. Subjects slept for about 5.5 hours the night before night shift 1, but before night shift 2 they slept more with an average of about 6 hours in the older group and 7.5 hours in the younger group (table 4). If reductions in sleep duration are the primary cause of the differences in performance between the age groups, or even if they exacerbate the impact of the circadian system, then factors known to impact on sleep such as age and competing social or domestic activities may play more of a part in the real world.

In an attempt to relate the impairment of performance found in this study to some commonly understood index, we compared the results from night shift 1 with a previous study of ours with the same performance task.³² The article by Dawson and Reid³² suggested that the impairment in performance after 24 hours of sustained wakefulness is equivalent to the impairment in performance recorded at a blood alcohol concentration of 0.1%. In the study by Dawson and Reid,³² performance in healthy young subjects was reduced by about 8.5% between 13 and 25 hours of wakefulness during the night. In the current study performance between 13 and 25 hours of wakefulness at the same time of day on the same task was reduced by about 4% for the younger subjects and 6% for the older subjects. At least for the younger subjects the discrepancy between these studies may be due to the frequency of testing. In the current study, performance testing started at 13 hours of wakefulness and was conducted every hour, whereas performance in the study of Dawson and Reid³² was tested every 30 minutes for 28 hours of wakefulness. The previous 13 hours of testing may account for the decreased performance in the earlier study; however, this does not account for the discrepancy in performance between the older and younger subjects in the current study. Taking the results of the two studies into account we hypothesise that it may take less hours of wakefulness in the older subjects to reach a performance decrement equivalent to a blood alcohol concentration of 0.1%.

Another factor to consider is that there are likely to be alterations in performance if the order of shift rotation is changed from day, day, night, night (DDNN) to NNDD. When doing an NNDD rotation the impairment in performance on the first night shift might be lower than on the DDNN rotation, because there would not have been two previous nights of reduced sleep. This effect may only be

minimal, however, as there would still be the influence of previous hours of wakefulness and circadian systems on performance. It also seems unlikely that there would be a difference in the relation between the young and the older subjects, rather only a difference in the pattern of performance in each group. Furthermore doing the NNDD schedule may be harder because there may be some adaptation of the circadian system to the night shifts before doing the day shifts, at least in the younger subjects.³⁶ With these factors in mind it is difficult to determine whether there would be any discernable benefit to doing the rotation one way or the other.

Finally it is important to note that subjects in the current study were tested under laboratory conditions for only one shift rotation and that performance decrements may differ in a real world over an extended period. There may also be a significant self selection factor in people who choose to continue working shift work schedules in the real world. It is difficult to ascertain the impact of shift work experience on performance in the current study because we did not record it. Furthermore, just because there are decreases in performance in this study does not necessarily mean that there will be a corresponding decrease in performance in the real world either on this test, on work performance, or an increase in rates of accidents. This study does highlight, however, the importance of further studies to investigate the impact of age on worker performance to ensure that workers' safety is not compromised.

In summary, this study suggests that age is an important factor in influencing performance both in baseline conditions and during a 12 hour shift rotation. It could also be suggested that older people may be more sensitive to the influence of the circadian system, time of day, or sleep disruption during a 12 hour shift rotation than are younger people.

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