

# Reaction Time Measurement in Different Periods of Shift Work at Nurses

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## Abstract

Shift work is associated with increased risk of health problems. We chose to test the parameters of wakefulness at shift-working nurses using the Performance Vigilance Task (PVT-192). The visual analogue scale of sleepiness (VAS) and selected sleep history data were included in the investigation.

20 nurses working in a 12-hour rotating shift regimen were included. Exclusion criteria comprised the use of sleep-modulating drugs, the presence of history-based sleep disorders, morbidity. Each of the nurses underwent a total of four PVT tests, before and then after her (day or night) duty.

The reaction time (RT) mean value before the day shift was 261.3ms (SD±38.7), after the day shift 260.1ms (SD±33.1), before the night shift 251.3ms (SD±23.5), after the night shift 260.5ms (SD±26.1). There were significant differences in RT before and after the night duty, and between the RT of both evening measurements. The difference in RT before and after duty was significantly greater after night shifts.

There was a significant difference between the rate of PVT test errors before the day shift and after the night shift.

VAS-based subjective rating of daytime sleepiness was 3.3 (SD±2.2) before and 3.5 (SD±2.8) after the day shift, 3.1 (SD±2.4) before and 5.9 (SD±2.3) after the night shift. There was a significant difference between VAS before and after night shifts, and a significant difference in the VAS difference between the beginning and end of the night shift in comparison with the day shift. Clearly enough, the circadian aspect has a major role to play in the testing.

## INTRODUCTION

Some 20–25% of the working population, i.e., roughly 5–8% of the entire population in the developed countries, are engaged in shift work (Turek 2005; AASM 2005). The term is understood to mean the performance of working activities during the hours of habitual sleep requirement. Shift work operations are typical of, in particular, the sectors of transporta-

tion, services, communications, industry, health and defence. Employees working in the rotating shift system are, in general, known to be prone to increased morbidity. The main health risks include disorders of mood – especially the depressive syndrome, also reported are increased risk of obesity, cardiovascular diseases, dyspepsia, gastric ulcer disease, abuse of

addictive drugs and, in women, increased risk of contracting breast cancer (Gold *et al* 1992; Drake *et al* 2004; Knutsson 2003; Boggild & Knutsson 1999; Schernhammer *et al* 2001). Disorders of sleep trouble up to 80% of all shiftworkers (Akerstedt 1988). According to the International Classification of Sleep Disorders (ICSD-2) (AASM 2005), shiftwork-related disorders of sleep are classified as circadian rhythm disturbances. In the rotating shift regimen, these include both insomnia (sleep initiation and maintenance disorder) and excessive sleepiness. Circadian rhythm disorders develop as a result of desynchronisation between the internal time pacemaker in the nucleus suprachiasmaticus and external factors (Hastings *et al* 2003).

The main external factors influencing people's "inner clock" include particularly a regular rhythm of light and dark alternation, but also food intake, physical activity, occupational and social activities, etc. In a shiftwork regimen, sleep is mistimed, of poor quality, fragmented, marked by 2NREM and REM sleep reduction, threatened shortening of sleep latency and sometimes even REM sleep latency (Akerstedt 1985; Akerstedt 2003). Shift working people are reported to sleep anything up to 10 hours less weekly than those working fixed regular hours (Knauth *et al* 1980; Tasto & Colligan 1978). Hence, shift work can be the cause of chronic sleep deprivation. Disordered sleep may lead to attention disorders, states of irritation, impaired work performance, an increased risk of errors at work and to traffic accidents (an up to 3.6 times greater risk after a night duty) (Gold *et al* 1992; Rogers *et al* 2001; Steele *et al* 1999). There are also frequent family and social problems resulting from desynchronisation between the usual rhythm in society and the sleep/wake rhythm of shift workers.

The purpose of our study was to find out whether or not shift work has an impact on some of the parameters of wakefulness, especially on reaction time and attention.

## METHOD

To test shift work influence on vigilance and attention, we chose the Performance Vigilance Task (PVT-192) (Dinges & Powell 1985). This is an outpatient method for testing the impact of sleep deprivation, attention and the effects of medication. PVT is a portable system regarded as analogous to the multiple sleep latency test (MSLT), which, however, is used in a sleep laboratory (Carskadon *et al* 1986). The point of the PVT test is to respond by the fastest possible button press to light impulses popping up irregularly on the PVT display. The test takes 10 minutes to complete. The PVT software helps to rate the reaction times (RT) and number of errors made during the test. PVT also enables automatic retrieval and mathematical processing of the data obtained – mean, average, 10% of the shortest and longest RT values, standard deviation, and the like. Beside

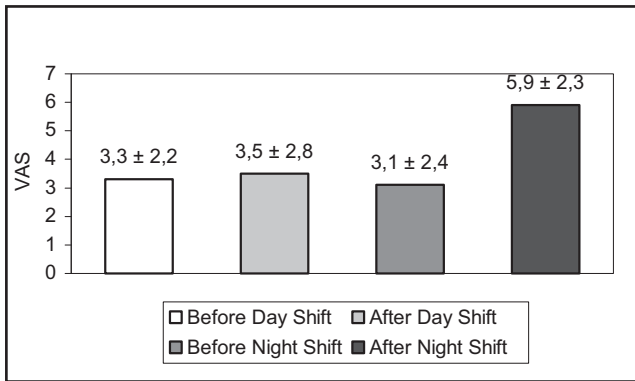
speed of response in each of the tests, it is important to take into account the number of errors, in particular, lapses, i.e., responses longer than 500 ms (regarded as equivalent to falling asleep in the MSLT) and premature button presses or false starts (FS) such as may reflect vigilance and attention variability. Some of the results can also be obtained in graphic form.

Our study was designed to test shift work rhythm for its effect on waking and attention in health-care nurses. After obtaining their oral informed consent, 20 nurses employed at a department of neurology in a 12-hour shift work regimen were enrolled in the study. The criteria for exclusion were as follows: history-based organic sleep disorders such as sleep apnoea, restless legs syndrome and periodic limb movements in sleep, any type of sleep-modulating medication, serious internal involvement, mood disturbances and endocrine diseases, especially thyroid gland disorders. The participating nurses were asked to refrain from drinking coffee or smoking cigarettes before the testing. Each of them was PVT-tested before starting her day shift (6–7 a.m.) and then after its end (6–7 p.m.), and again before (6–7 p.m.) and after her night shift (6–7 a.m.). In other words, every subject under study underwent a total of four PVT tests scheduled in a random order. The investigation included the participants' own subjective rating of daytime sleepiness, using the visual analogue scale (VAS). This was completed once at each test. The actual tendency toward falling asleep was also rated as part of the PVT test where the set displayed this particular question in the form of a scale each time at the beginning and at the end of the testing. For other history data, a questionnaire was provided. In it, the nurses were asked to answer questions concerning smoking, coffee and caffeine drinks consumption, number of children, number of night duties per months, habitual sleep times, number of days from the last night shift, but also about the duration of sleep before the night shift tested, duration of sleep after the night shift, duration of sleep before the day duty, and the hour of early-morning rising before the day shift tested. (Tab1).

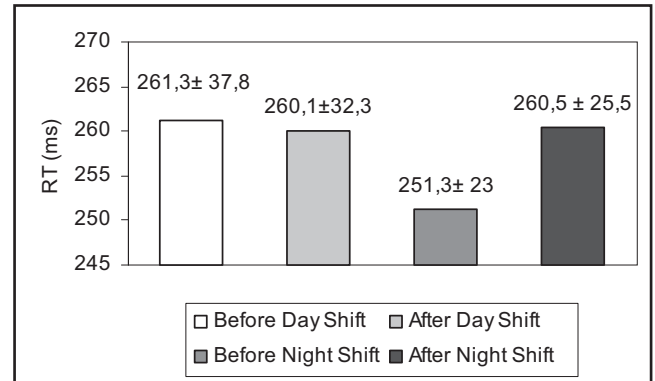
Selected parameters were subsequently compared in a number of statistical tests designed to compare the results of the tests between one another, and then with selected medical history data. The ANOVA, T-test, Spearman's test and the gamma correlation tests were used for assessing the results.

## RESULTS

The results of the participants' subjective rating of their fleeting drowsiness were as follows (0 – no sleepiness, 10 – maximum sleepiness): the mean VAS value before the day shift was 3.3 (SD±2.2), after the day shift 3.5 (SD±2.8), prior to the night shift 3.1 (SD±2.4), and 5.9 (SD±2.3) after the night shift (**Figure 1**). There was a significant VAS difference before and after the night shift (ANOVA,  $df=57$ ,  $F=5.49$ ,  $p=0.0011$ ) and also in



**Figure 1.** Visual Analogue Scale (VAS) of sleepiness in each test (0 – no sleepiness, 10- maximum sleepiness)



**Figure 2.** Reaction time (RT) (mean) in each test

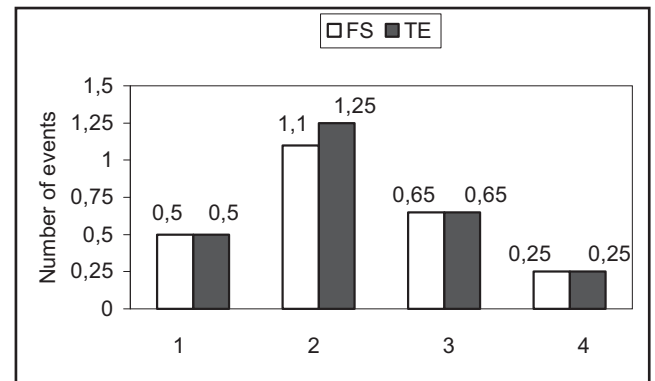
the VAS difference between the shift beginning and end after the night shift as distinct from the day shift (i.e., difference in the buildup of sleepiness) (T-test,  $p=0.0041$ ).

Subjective rating of sleepiness according to PVT was as follows (1 – minimum sleepiness, 7 – maximum sleepiness): prior to the day shift before and after testing respectively 4.3 ( $\pm 2.8$ ) and 5.3 ( $\pm 3.1$ ) resp., after the day shift before and after testing respectively 4.3 ( $\pm 2.8$ ) and 5.0 ( $\pm 3.1$ ) resp., prior to the night shift before and after testing respectively 3.3 ( $\pm 2.7$ ) and 3.3 ( $\pm 2.7$ ) resp., and after the night shift before and after testing respectively 5.9 ( $\pm 2.3$ ) and 6.8 ( $\pm 2.3$ ) resp.

As to the subjective rating of sleepiness, the only statistically significant difference was found during the night shift – both before (ANOVA,  $df=57$ ,  $F=5.49$ ,  $p=0.0022$ ) and after testing (ANOVA,  $df=57$ ,  $F=8.54$ ,  $p=0.0001$ ). Hence, subjective sleepiness is more pronounced after the night shift than before it, and the sleep debt resulting from the night shift is greater than that resulting from the day shift.

As for objective PVT measurements, we were mainly interested in comparing the tests for reaction times. The reaction time (RT) mean value before the day shift was 261.3ms ( $SD\pm 37.8$ ), after the day shift 260.1ms ( $SD\pm 32.3$ ), before the night shift 251.3ms ( $SD\pm 23$ ), after the night shift 260.5ms ( $SD\pm 25.5$ ) (**Figure 2**). There were no significant reaction time differences between the particular measurements. The only statistically significant difference was found in the reaction time difference between the beginning and end of the shift, in particular, a significantly greater difference after the night duty than after the day duty (T-test,  $p=0.0370$ ). In other words, sleep deprivation leads to longer reaction time.

We also compared the tests for minimum and maximum reaction time values. Rated as statistically significant was the difference in the difference of the average 10% of the shortest for a drop in the number of reaction times between the day shift and the night shift – a drop



**Figure 3.** Mean number of false starts (FS) and total errors (TE) in each test. 1 - Before day shift 2 - After day shift 3 - Before night shift 4 - After night shift

in 10% of the shortest RT after the night shift when compared with the day shift (T-test,  $p=0.0013$ ). This shows, just as much as comparisons of the RT mean values, that sleep deficit is coresponsible for reaction time lengthening and/or the fastest responses.

The average number of total errors (TE) was before and after the day shift 0.5 ( $SD\pm 1$ ) and 1.25 ( $SD\pm 1.62$ ) respectively, and before and after the night shift 0.65 ( $SD\pm 0.93$ ) and 0.25 ( $SD\pm 0.91$ ) respectively (**Figure 3**). A statistically significant difference was found in the average rate of TE both after the day shift and after the night shift (ANOVA,  $df=57$ ,  $F=5.65$ ,  $p=0.0018$ ) and in the difference in the rate of reaction times, a value significantly higher after the day shift than after the night shift (T-test,  $p=0.0140$ ).

The average number of false starts (FS) prior to and after the day shift was 0.5 ( $SD\pm 1$ ) and 1.1 ( $SD\pm 1.48$ ) respectively, and prior to and after the night shift 0.65 ( $SD\pm 0.93$ ) and 0.25 ( $SD\pm 0.91$ ) respectively (**Figure 3**). A significant difference was found between measurements after the day shift as distinct from the night shift (ANOVA,  $df=57$ ,  $F=4.71$ ,  $p=0.0052$ ). There was also a significant difference in the difference in the number of FS between the beginning and the end of the shift (day 0.6, night -0.4), (T-test,  $p=0.0023$ ). Paradoxically then, the rate of test errors was found decreasing after the night shift.

**Tab 1.** General characteristic of the group and working regimen.

mean age	35 years	(SD ± 13)
9 smokers		
18 regular coffee drinkers	(mean twice a shift)	
15 have children		
<b>Work regimen information:</b>		
number of shifts per month	7.5	(SD ± 0.8)
usual sleep requirement	7.7 hours	(SD ± 1.4)
time of sleep after night shift	4.5 hours	(SD ± 1.5)
time of sleep before day shift	5.9 hours	(SD ± 1,7)
waking time before day shift	5 – 5.45 a.m.	
number of days from last night shift to the night shift tested	3.6	(SD ± 2.4)
time of sleep before night shift	6.7 hours	(SD ± 2.8)

No significant difference between measurements was found in the average number of lapses.

The following correlations were ascertained when selected medical history parameters were compared with the results of measurements. Statistical significance was found in the negative correlation between the nurses' age or number of children and the duration of sleep after the night shift respectively (Spearman  $p=0.0147$ , gamma correlation  $p=0.0040$  resp.  $p=0.0106$ , gamma correlation  $p=0.0023$ ) and in the negative correlation between the nurses' number of children and number of night shifts (gamma correlation  $p=0.0051$ ), positive correlation between the women's age or number of children and the difference in the day-shift mean reaction time (Spearman,  $p=0.0267$  and  $0.0202$  respectively), positive correlation between the hour of rising and the difference in the day-shift mean reaction time (Spearman,  $p=0.0383$ ), and a negative correlation between the subjects' age and the increase in the number of lapses during the night shift (Spearman,  $p=0.0107$ ). No difference in the parameters under study was found between smokers and non-smokers.

## CONCLUSION AND DISCUSSION:

Due to the effect of acute sleep deprivation, the need for sleep is greater after the night shift, and the subject feels more sleepy. As in other studies, objective measurement brought evidence of sleep deprivation being associated with reaction time lengthening (though not significantly so). What came as a surprise was that under the effect of sleep deprivation after night shifts there were significantly fewer errors than in other measurements. This phenomenon has never been reported before and, given the number of the study subjects, the finding is open to discussion. A possible explanation may lie in that the nurses in a state of sleep deprivation were aware of the risk of error, which was why they paid more

attention to the testing. It is reported that while after a night duty shift workers are aware of their drowsiness, they are frequently unaware of short naps (Landrigan *et al* 2004).

We found older age leading to RT lengthening solely during the day shift. According to other authors, older age is generally associated with RT prolongation, though subjective rating of daytime sleepiness is lower than in younger individuals (not to our observations).

As shown by the positive correlation between age and the number of lapses after night shifts, older nurses can better tolerate sleep deprivation, albeit at the cost of reaction time lengthening. Post-night-shift tests on driving simulators found increased electroencephalographic (EEG) alpha and theta activities (Akerstedt *et al* 2005) where EEG changes were associated with spells of attention deficit and increased proneness to traffic accidents (Bjerner 1949; Reyner & Horne 1998).

None of the nurses reported any error at work due to post-shift sleepiness (according to another study, the risk of such errors is twice as great there) (Rogers *et al* 2001), though this ought to be taken with great caution. None of the study nurses use hypnotics to induce sleep after night duties though rotating shift workers are generally reported to have an increased consumption of hypnotics. Since the feeling of drowsiness is always greater after the test than before, it is a safe assumption that monotonous activity, too, leads to a drop in subjective wakefulness.

Post-night-shift daytime sleep shows age-related shortening, with the time spent asleep after a night duty being the shorter, the more children the nurses have, considering that nurses with more children are assigned fewer night duties.

The results show that beside being due to shift work the parameters of wakefulness also indicate variations in physiological circadian rhythmicity.

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