Effects of working permanent night shifts and two shifts on cognitive and psychomotor performance

Abstract Objectives: The study aimed to clarify whether cognitive and psychomotor performance, which are important for occupational and traffic safety, are impaired by working permanent night shifts (NSs) compared with early–late two shifts (TSs) and whether age and chronobiological type influences the relationship between shift and performance. Methods: The study included 44 male automobile workers, 20 working TSs and 24 working NSs. Chronobiological type was determined by questionnaire (D-MEQ). Each subject was tested at the beginning and end of the shift for alertness [by a visual analogue scale (VAS)]; feeling of well-being (Basler); concentration and accuracy (d2); reaction speed, orientation and reaction to stress (Vienna System). Results: TS workers were more frequently morning types whereas the NS workers were more frequently evening types. In the performance tests, the TS and NS workers did not differ at shift start or shift end. Over the course of the shift, concentration and accuracy improved in both groups, as did reaction to stress. Chronobiological type alone or in combination with shift type had no effect on performance. Conclusions: The results of this study indicate that—if chosen voluntarily—working NSs has no immediate negative effects on cognitive and psychomotor performance when compared with working TSs. There was no indication of an increased risk of accidents after working NSs. The unequal distribution of the circadian types in the shift groups may indicate selection.

Keywords Permanent night work · Safety · Fatigue · Alertness · Chronobibiological type

Introduction

Shift work in general, but especially night shift work, presents a significant problem with regard to well-being, health, and occupational safety (Harma 1998). In contrast to many other potential factors, which are harmful to health at the workplace, shift work generally cannot be avoided. Shift work is increasingly necessary to provide services around the clock. According to actual estimates, 17.6% of employees in Europe work at least 25% of their time at night (Weddenburn 1996).

Willingness to work shifts is a pre-requisite for certain jobs. A special situation is presented by shifts, in which 16 h of the day are covered by rotating shifts [two shifts (TS)], i.e. early and late shifts, and the night is covered by permanent night shift (NS) work. These shifts are important in large industries, traffic departments or in the healthcare system. Advantages of NS are the following: working NS is usually a voluntary decision, there is a high degree of satisfaction with the work situation when compared with other shift systems and there is minimal subjective impairment (Barton 1994; Brooks 1997; Gillberg 1998; Wilkinson 1992). Based on a series of isolated findings, a disadvantage of this system is that NS is regarded as physiologically harmful, since many body functions follow a circadian rhythm and reach their peak during the day (Knauth 1995).

An individual’s adaptation to shift work depends partly on circadian type and on changes in the individual’s daily rhythm (Griefahn et al. 2002; Roenneberg 2003). Age is also an important factor, since the circadian rhythm of people older than 40 years seems to be less adaptable (Reid and Dawson 2001).
During night work in TSs, there is a decrease in one’s ability to concentrate and in one’s performance, quality of performance, alertness and ability to react, while fatigue and the rate of mistakes increases (Frey et al. 2002; Lingenfelser et al. 1994; Smith et al. 1994). Late shifts and night shifts are associated with an increased risk of occupational accidents (Folkard 1997; Hanecke et al. 1998; Knauth 1998; Smith et al. 1994). Workers returning home from night shifts have an especially high risk of having traffic accidents (Monk et al. 1996; Stutts et al. 2003).

Data regarding the effects of NS work on cognitive and psychomotor performance are scant and incomplete. Furthermore, most studies were performed in a laboratory setting. Specifically, it is unknown whether NSs affect the ability to drive a vehicle and thereby leads to decreased traffic safety on the way to and from work.

The present study aimed to clarify whether—in a real life situation—capabilities required for work and traffic safety are more strongly impaired by NS work than by TS work. Specifically, the following questions were investigated:

1. Does cognitive and psychomotor performance differ at the beginning and the end of the shift and/or is the change during the NS different when compared with the change during the TS?
2. Does performance decrease during either of the shifts to below the minimally required level, which according to the law are pre-requisites for obtaining a professional driver’s licence?
3. Do age and circadian type affect the change in performance during a shift and the performance level at the beginning versus at the end of a shift?

**Subjects and methods**

The study was performed in an automobile production plant with approximately 30,000 workers. The participants in the study were recruited from everybody working in the factory subdivisions—raw construction, sheet-metal shop, and paint shop—who were working on the shifts to be studied. Those that were included required a routine occupational screening examination during a defined time period in the factory’s medical centre and were informed prior to the appointment about possible participation in the study. All workers who appeared during the first hour of the shift for the screening examination within a defined 5-day period (one working week) and who consented orally and in writing to participate in the study, were included. The ethics committee of the University of Munich approved the study.

An inclusion criterion was shift work, either on TSs, which included a week of early shifts (0600–1430 hours) alternating with a week of late shifts (1430–2230 hours), or on NSs (2230–0600 hours). The shift week began on the Monday and ended on the Saturday morning. The persons on TSs were examined only in the early shift. The examination was possible between the first and the fifth day of the shift week. The inclusion criterion “factory subdivisions” served to keep the groups as typical, representative and homogeneous as possible with regard to working conditions and training level. Exclusion criteria were poor German language skills or motor capabilities and poor visual acuity. On the basis of these criteria, one subject from the TSs and one from the NSs were excluded from the study.

Of the 51 male workers asked to participate, three could not be included due to other duties at the same time, four refused to consent, and 44 persons were included in the study. Of these, 20 worked on TSs and 24 worked on NSs. The median age of all subjects was 39 years, and the age of TS workers ranged from 21 years to 56 years (mean ± standard deviation 38.7 ± 11.9 years); continuous employment on this type of shift ranged between 2 years and 37 years (14.9 ± 2.7 years). The age of NS workers ranged from 26 years to 58 years (38.9 ± 9.2 years) and the duration of employment on this type of shift was between 0.17 years and 25 years (7.5 ± 5.9 years). For analysis, the subjects were split into two age categories: equal to or below median and above median. On TSs, nine subjects were equal to or below 39 years of age and 11 were above, whereas, on NSs, 15 subjects were equal to or below 39 years of age and nine were above.

**Study design and examination schedule**

Each subject was examined twice during the same shift. The first examination was performed during the first 90 min of the shift, and the last examination during the last 90 min, for both TSs and NSs. Examinations were not started at a later time, in order for us to keep the time periods between the examinations sufficiently long. Thus, approximately four to six persons could be examined per shift.

**Questionnaires**

At the start of the shift, each subject filled in a short questionnaire that documented personal data, duration of employment in the particular shift, and accidents on the way to and from work (car accidents, etc.) and, if yes, in relation to which shift the accident occurred.

The D-MEQ (German version of the Morningness—Eveningness Questionnaire by Horne and Ostberg) was also filled in by each subject at the beginning of the shift. The questionnaire allows the chronobiological circadian type to be determined (Griefahn 2002). The answers to the 19 questions are assigned scores, which are added together. Based on this sum, subjects are divided into five categories: definitive scores, moderate evening type, neutral type, moderate morning type and definitive morning type.
Before and after the shift, the degree of subjective alertness was recorded with the help of a visual analogue scale (VAS) (McCormack et al. 1988). The subjects were asked to estimate their state of alertness on a scale-less line with two end points, “very tired” (0 points) and “wide awake” (10 points).

At the beginning and end of the shift, subjective wellbeing was rated with the help of the Basler rating scale of subjective well-being. This contains 16 pairs of words from which the subject chooses which word of a pair accurately describes the current situation. A score is assigned, depending on which word of the pair is chosen. The word pairs (items) are grouped into four factors, and the scores of all items within each factor are added together. These four factors are vitality (VT), intrapsychic balance (IB), degree of social extroversion (SE) and vigilance (VG) (Hobi 1985; Riedel et al. 1993; Wichers et al. 1999). Vitality refers to mental and physical vigour; the intrapsychic balance describes the inner mental balance; the degree of social extroversion refers to the ability and willingness to form social contacts; and vigilance refers to the ability to direct one’s attention to something new. The score ranged for each factor from 4 to 28 points. It took approximately 10 min to complete the questionnaires.

Performance tests

These tests were performed at the beginning and end of the shift. Before it was started, each test was explained in a standardised manner followed by a short training period. Only after the subject showed correct comprehension of the test did the real test session start. In order for an individual to obtain a driver’s licence for professional conveyance of passengers, in Germany there are minimum cognitive and psychomotor capability levels required by law. These include ability to deal with stress, to react, to concentrate, and orientation and attention ability. At least three test methods must be used, and, for most methods, the score must be equal to or above the 33rd percentile of the age-independent norm. The capabilities defined by these psychological tests are used here as intermediate endpoints for traffic safety. The procedures are a standard part of the driver’s test in Germany and they fulfill the requirements of safety. The procedures are a standard part of the driver’s test. Before each test there is a practice phase.

The Vienna test system is a computer-supported test system that also assesses the capabilities that are important for the driver’s licence (Neuwirth 2002). The following tests were performed in the given sequence: the Vienna reaction test (RT), the line-marking test (LMT) and the Vienna determination test (DT). The subject is automatically instructed by the test programme, and before each test there is a practice phase.

The RT measures the reaction time and the alertness (Kotterba et al. 1998; Neuwirth 2002). The subject should only react to specific visual and auditory stimuli. The median reaction time (primary variable) and the number of stimuli to which a correct or incorrect reaction (secondary variable) was made are calculated.

The LMT determines visual alertness. The subject should follow a line from its starting point to its end point in a series of pictures that show intertwined lines. The number of correct answers (exactness of test completion) and the median reaction time (quickness) are recorded. The final score is the product of these two measurements and reflects both the speed and the quality of test completion. High scores correspond to quick and exact perceptive abilities.

The DT measures attention deficits, reaction speed, and the relative capacity to deal with stress. The capacity to deal with stress is the ability of the individual to counter provocative stimuli, i.e. to activate behaviour that allows optimal coping with the situation (Neuwirth 2002). The reaction to a combination of stimuli (visual and auditory) was studied. The subjects were deliberately set in an excessively demanding situation that they could not manage appropriately. The primary variable measured was the number of correct reactions, and the secondary variable was the number of incorrect reactions.

In particular, the tests used from the Vienna test system (LMT, DT) and the “d2” test correlate very well with the ability to drive vehicles, accident frequency and accident risk (Brickenkamp 2002; Bukasa et al. 1990; Karner and Neuwirth 2000). The performance tests required approximately 30 min.

Analysis of the data

The collected data were entered into the database via double-data entry and were tested for correctness and plausibility and for normal distribution with the Kolmogorov-Smirnov test.
The measured values were compared between workers on the TSs and those on the NSs, between subjects ≤ 39 years old and those >39 years, between the various circadian types and between the various shift days (day 1 to day 5) on which the examination was performed.

Between the groups of the TS and the NS workers, the differences between shift start and shift end were tested with the *t* test for paired samples, since all variables were normally distributed.

We tested for differences in the baseline data, in the rating of subjective alertness and well-being, and in performance (at shift beginning, at shift end and the difference between the beginning and the end of the shift) between the two shift types, the age groups, the circadian types and the shift days, with the chi-squared test for frequency tables, the *t* test for independent samples or with one-way ANOVA, depending on the characteristics of the data.

Combined effects of shift type, age, circadian type and shift day (i.e. shift type × age; shift type × circadian type, etc.) were analysed by a univariate analysis of variance according to the method of general linear models (GLMs).

 Associations between the rating of subjective alertness and well-being and performance were analysed with the bivariate Pearson’s correlation.

The performance in each of the three Vienna system tests (RT, LMT, DT) was compared to the expected values for the normal population (independent of age), as is usual in psychological traffic testing. Whether the required 33rd percentile was attained was also checked.

### Results

None of the workers employed on the NS reported an accident after a shift in the past. Two TS workers each reported an accident on the way home from work; one accident occurred after the early shift and the other after a NS (while working NSs in the past).

Extreme circadian types (definitive evening or morning type) were not present in this group (Table 1). Most persons had a neutral circadian type. TS workers differed from NS workers with regard to their circadian type: there were more morning types among the TS workers, whereas there were more evening types among the NS workers.

<table>
<thead>
<tr>
<th>Shift</th>
<th>Circadian type</th>
<th>Moderate morning type</th>
<th>Neutral type</th>
<th>Moderate evening type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two shift</td>
<td>7 (35%)</td>
<td>13 (65%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Permanent night shift</td>
<td>1 (4.2%)</td>
<td>15 (62.5%)</td>
<td>8 (33.3%)</td>
<td></td>
</tr>
</tbody>
</table>

The rating of subjective alertness and well-being prior to and after the shift are shown separately for TS and NS workers in Table 2. At the beginning of the NS, workers differ from those on the TS because of a higher rating of subjective alertness and certain variables of well-being: they felt significantly more awake, vital and alert. At the end of the shift, the two groups did not differ. Comparing the end of the shift with its beginning, we found that the vitality of the TS and NS workers decreased. The alertness and vigilance of the NS workers also decreased during the shift. However, the change in the state of alertness and well-being during the course of the shift was not significantly different between TS and the NS workers. With regard to mental balance and social extroversion, there was no difference between the NS and the TS workers, either at the start or at the end of the shift.

An effect of circadian type on the rating of subjective alertness and well-being was not observed. An effect of age on the rating of subjective alertness and well-being was detectable at the beginning and during the course of the shift only for mental balance: younger workers felt themselves to be more balanced at the beginning of the shift than did older workers (data not shown). At the end of the shift there was no difference between the two age groups.

A combined effect of circadian type and shift or age and shift on the rating of subjective alertness and well-being was also not seen.

The results for cognitive and psychomotor capabilities are shown in Table 3. Workers on TSs and NSs did not differ at the beginning or the end of the shift, nor in the difference between the end and the beginning of the shift with regard to the CP and the F% in the d2-test, the reaction speed in the RT, the score of the LMT, and the number of correct and incorrect reactions to the stimuli in the DT. In both shift groups, the CP and the F% improved during the shift, to similar degrees. The median reaction time in the RT, and the score of the LMT, did not change. In the DT, the number of correct and incorrect reactions of the TS workers increased during the course of the shift. The NS workers improved only in the number of correct reactions, while the number of incorrect reactions remained almost unchanged.

Age had an effect on the performance at shift start and shift end: workers younger than 39 years attained better scores for all performance parameters at the start and at the end of the shift than did workers older than 39 years, with the exception of the number of incorrect reactions in the DT (data not shown). The change in the performance parameters was similar for both age groups. Combined with the shift, age had no effect on the measured performance. Circadian type had neither an independent effect nor an effect when combined with the shift on the measured performance (data not shown).

Nine subjects (seven older than and two younger than 39 years of age) did not achieve the minimal level of
psychomotor performance required for professional conveyance of passengers, either at shift start or at shift end. At the beginning of the shift, ten people were below the 33rd percentile (in at least one test), five working on the TSs (all older than 39 years) and five working on the NSs (three older and two younger than 39 years of age). Of these, four of the TS workers and all five of the NS workers also had a score below the 33rd percentile at the end of the shift. The scores of three persons worsened in one of the tests of the Vienna test system, from a normal value at shift start to a value below the minimum requirement at shift end. In the RT at shift end, one subject in each shift type (TS, NS) below the age of 39 years had a score below the 33rd percentile. One worker older than 39 years was below this limit in the LMT.

Table 4 shows the number of workers who were examined on the different shift days. There was no difference in the rating of subjective alertness and well-being or in the performance between the shift days, either in the entire group or within either shift group. When the variable “shift day” was treated as a potential confounder in the GLM analysis, the relationship between shift group, subjective alertness and well-being or performance remained unchanged. This indicates that the rating of subjective feelings and performance were independent of the shift day.

Discussion

Our study of shift workers at a large automobile plant showed no differences in the cognitive and psychomotor capabilities of NS workers before and after a shift compared with the capabilities of the TS workers. Fur-
thermore, no difference was found in the change of performance during the respective shift, the rating of subjective alertness and well-being at the end of the shift and the change in the rating of subjective alertness and well-being during the shift. Only at the beginning of the shift did NS workers feel more alert, more vital and more vigilant. In both groups, a similar improvement in the performance could be measured, which is interpreted primarily as a learning effect. The ability to learn was, therefore, equal in TS and in NS workers.

While there were more morning types among the TS workers, there were more evening types among the NS workers. An association between circadian type, performance, rating of subjective alertness and well-being and shift was not found. While older workers differed from younger ones because of worse values in the performance tests, the change over the shift was equal and independent of the shift type.

To our knowledge, the effects of permanent night work on performance and on the risk of accidents has not yet been examined. Our study has the advantage of reflecting a real-life situation, with regard to both the working conditions and the workers. The test methods used in this study to assess the psychomotor capabilities correspond to those used in Germany to determine an individual’s ability to drive a vehicle. Three subjects, of whom two worked TSs, attained a value at the shift end that was below the 33rd percentile, although they had normal values at the beginning of the shift. This indicates an impairment of driving ability by shift work; however, it does not indicate a specific accident risk due to working NSs. The overall number of reported accidents was small and did not differ between TS and NS workers. The small sample size does not allow general conclusions to be drawn.

Other studies investigated the effects of TS systems on cognitive and psychomotor capabilities. Most were experimental studies in laboratory conditions. They showed that the ability to react, alertness, capability to deal with stress, and concentration, are impaired in various shift systems, especially by night work and the resulting fatigue (Frey et al. 2002; Lingenfelser et al. 1994; Smith et al. 1994). Smith et al. (1994) showed that, during the night shift, the risk of accidents or injuries increases, which finding was also supported by Richardson et al. (1989). Those authors compared the TS workers with the day time workers and ascertained that more than 20% of TS workers had had an automobile accident due to fatigue in the past year. Horne and Reyner came to a similar conclusion (Horne and Reyner 1999). They found that night workers had an increased accident risk, especially in the early hours of the morning, in which fatigue was most prominent due to the circadian rhythm. It was assumed that the risk can be decreased considerably by a short sleep (Folkard 1997; Horne and Reyner 1999).

A typical problem of shift work is the discrepancy between the adaptation of the circadian rhythm necessary because of the work and the daily rhythm of the intermediate and broader social environment of the shift worker (Barton 1994; Colligan and Rosa 1990; Costa 1997). The work on permanent night work differs from the night shift work in rotating systems because it is often chosen voluntarily: according to information supplied by employers, there are more applicants for NS positions than there are positions. The high interest is explained, at present, because night work pays significantly more. The voluntary decision to switch from TS to NS includes the possibility to reverse the decision if the night work leads to impairment of well-being and health. Thus, NS is to a larger extent self-selected than is work in TS systems, which, as a rule, is compulsory for specific jobs. A possible result is that persons whose social environment and circadian type do not agree with night work also work less frequently on NSs, while evening types are more likely to choose NS work. Furthermore, NS differs from TSs because of the possibility for the worker to adapt over a long period (in extreme cases, over decades) to the night work. Those two differences are possible explanations as to why, in our study, the impaired performance observed in the TS workers was not seen in the NS workers.

An indication of selection and/or adaptation is the difference observed in circadian type between TS and NS workers. This is also supported indirectly by the lack of interaction between the circadian type and shift. Obviously, there are no persons on either TSs or NSs whose circadian type is in contrast to the performance required by the specific shift. Studies examining other shift systems showed a clear effect of the combination of shift and circadian type in the sense that “morning types” tolerated the early shift work better and tolerated the night shift work worse than the evening types (Folkard and Monk 1981; Hildebrandt et al. 1988; Ostberg 1973). Except for one person, no such combination was observed in our study.

In the factory subdivisions in which the study subjects were working, there were no workers with comparable responsibility and socio-economic status working exclusively day shifts. Therefore, we did not include a control group without shift work. We chose the early shift of the two-shift system as control (and not the late shift) because it is similar to a normal day shift (early shift starts at 0600 hours, day work at 0800 hours). The reduction of sleep before the morning shift observed in rapidly rotating shifts was not expected, since the two-shift workers worked the entire week in the morning and were thus adapted. Yet, it cannot be excluded that the lack of difference between NS and TS is due to a comparable negative effect of both shift types on performance.

Morning shifts take 1 h longer than the night shift and, thus, may be wearying. A small negative effect of night work may, thus, have been compensated for. We checked for this possibility by calculating the ratio of change during the shift by hours worked and found no difference in our results. Regardless of this, the current
practice of keeping night shifts shorter than day shifts eventually led to equal performance.

We also investigated the question of whether the adaptation to night work, which occurs during the week, is disturbed by activities at the weekend, so that a longer waking period results (i.e. continuously awake from Monday morning until Tuesday morning). In an experimental situation, it could be shown that the performance after 24 h of being awake decreased to a level comparable to the effect of a blood alcohol level of 1 promille (Reid and Dawson 1997). In our study, we did not observe a difference in the change of performance during the first night shift of NS workers compared to those examined at a later NS during the week. This indicates that the adaptation is preserved. This is supported by a study from Smith et al. (1994), in which no interaction between the frequency of accidents and the first or second half of the shift week was observed. In the TS workers, adaptation of the sleep–wake rhythm is further disturbed by the weekly change in shift. This is a possible reason for the lower rating of subjective perception of alertness, vitality and vigilance than that of the night workers, who have working hours that remain stable. On the other hand, the lack of effect of the shift day (implying adaptation within a week) does not support this.

On the basis of other studies, it was assumed that the performance would decrease with increasing age (Brickenkamp 2002; Reid and Dawson 2001). In a study by Reid and Dawson (2001) that assessed a 12-h shift in 32 subjects, there was a significant reduction in performance during the night shift. This reduction was greater in older subjects. Our study supports this finding only partly. Although the younger subjects achieved significantly better psychomotor and cognitive performance scores at the beginning and end of the respective shift, the effect of the shift work was similar in younger and older workers. This contrasts with the findings of Reid and Dawson (2001), which may be due to the difference in the length of the shift.

Because of our design the comparison was limited to morning shifts in two-shift systems and permanent night shift. Another limitation is the relatively small sample size for field studies, which makes the recognition of small differences difficult. Despite this small sample size, there was a significant difference with regard to the distribution of morning versus evening types. The results of the psychometric tests, on the other hand, revealed not even a trend in favour of the assumption that NSs would lead to worse test results. On the contrary, the small differences that could be observed pointed towards a slight worsening in the group of TS compared to NS workers. An a posteriori power analysis, within its inherent limitations, indicated that the magnitude of differences which could have been detected with a power of at least 80% at a significance levels of 5% was approximately two to ten times larger than the differences between groups that were actually observed. This suggests that large samples would have been required to render potential differences between groups statistically significant, particularly with regard to the concentration test and professional driver’s licence criteria. Whether such small differences, even if statistically significant, would have been of practical value, seems questionable. It should also be noted that the results of the psychometric methods that we used, and that are considered suitable to determine the individual’s ability to drive a vehicle, cannot replace traffic accident statistics, which would require a considerably larger study with respect to both sample size and length of observation period.

Although our study indicates some mechanisms of selection and adaptation, the number of workers leaving the NS, and the reasons for leaving, are unknown in our subjects.

In conclusion, we found no evidence in this study that self-chosen NS, in comparison with TS with early and late shifts, has a disadventageous effect on well-being and cognitive and psychomotor performance. Abilities that are important for driving a vehicle were, and remain, comparable in both shift types. Based on the participants’ accounts, there was no evidence for an increased number of accidents by NS workers. Possible reasons for the relatively favourable effect of the NS are selection and adaptation. This conclusion is drawn from the unequal distribution of the circadian types. The determination of accident frequency, long-term health effects and selection process remain the aim of a larger study.

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