Comparison of controller attention decrease during different break patterns in night shifts

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Night shifts result in a high pressure on employees' health. Regarding air traffic control, they may also represent a safety issue. Research showed that cognitive performance is decreased at night (Monk 1996) and safety risks increase starting from the second working hour without a break (Folkard et al. 2005). Investigating a request to extend the middle part of a night shift due to little traffic, different break patterns are compared in terms of avoiding health and safety issues. 189 air traffic controllers (ATCOs) from the Eurocontrol Maastricht Upper Area Control Centre in the Netherlands were tested during night shifts lasting for 7.5 hours. During the night shift, two teams, each consisting of two air traffic controllers, were working: While one team was on break, the other took over. They were assigned to three break patterns, with four or five hours of break or a split of the night shift. Each team was tested three times during normal operation. They estimated their subjective sleepiness using a subjective measure, the Stanford Sleepiness Scale, and filled in an objective measure, the *d2*, to measure attention. Furthermore, one measurement took place during a regular day shift in order to control the night shift data. Results show that five hours of working without a break does not have a negative impact on attention compared to the two other work-break patterns. External validity is given, since the study was conducted during normal operation. However, it was not possible to control and evaluate all confounding variables, as this would have disturbed the ongoing safe working processes of the scheduled shifts. Therefore, future research that examines individual differences in attention and considers the different activities during the breaks of the ATCOs still needs to be conducted in order to clearly identify an optimal break pattern for night shifts.

INTRODUCTION

Plenty of research has been carried out on fatigue, shift work, and attention. Several authors were able to demonstrate a negative influence of shift work on workers (Costa, Lievore, Casaletti, Gaffuri & Folkard, 1989; Gold et al., 1992; Monk, 1986; Rosekind et al., 1994), especially when they are working at night (Touitou et al., 1990; Folkard & Condon, 1987; Folkard, 1992; Dahlgren, 1981). A few studies have investigated the influence of breaks during night shifts (Folkard & Tucker, 2003; Hopkin, 19955; Purnell, Feyer & Herbison, 2002; Rocco et al., 2000; Weinger, 1999).

In their meta-study on safety in shift work, Folkard, Lombardi and Tucker (2005) found that the safety risk increases from the second to the fifth hour on shift and that the "risk increased in an approximately exponential fashion with time on shift" (Folkard, Lombardi & Tucker 2005, p.21). Szalma et al. (2004), using the NASA Task Load Index, found a decrease in visual attention from 90 to 60 percent after 40 minutes.

In Air Traffic Control, accidents and incidents do not only occur when the ATCOs are under stress; boredom, which is more likely to occur at night, can lead to incidents and accidents due to reduced situational awareness (EATM, 2006). In his meta-analysis of studies indicating incidence of falling asleep at the wheel, Monk (1996) showed that fatigue, as perceived during the night when working against the circadian rhythm, seems to have a particular impact on safety. He also inferred that reduced performance associated with sleepiness is closely related to working at night.

In general, breaks are particularly essential at night to ensure the successful detection of problems (Weinger, 1999). Without adequate breaks, attention and alertness on position cannot be guaranteed. Elsewhere, it has been argued that during the night, the traffic decreases to such an extent that breaks are not as necessary as during the day shift. However, "light traffic loading is not an adequate reason for dispensing with rest breaks" (Hopkin, 1995, p. 366).

In fact, it was even found that monotonous work adversely influences vigilance and may act as a multiplier of fatigue and sleepiness (Dinges, 1995; Thiffault & Bergeron, 2003). Visual attention is also reduced when observers have to react to rare stimulus events compared to reacting to frequently occurring stimuli (MacLean et al., 2009). Larue et al. (2010) state that a monotonous task causes a reduction in sustained attention compared to a non-monotonous task. While sleep deprivation – as often seen in night shift work – seems to have no influence on sustained attention performance during a cognitively challenging task, attention was found to decrease significantly within a non-challenging task (Pilcher et al., 2007).

Therefore, especially at night, breaks should be taken at least every second hour instead of when the ATCOs are exhausted due to their high workload.

Hahn (1988) suggests a 15-minute break within the first third of a night shift and half an hour after the second third. In addition, he recommends hourly short breaks. However, considering that traffic must be observed at all times, hourly breaks may not be appropriate for air traffic control (ATC). In their study on night shift work, Rocco et al. (2000) found that breaks alone are not enough to prevent errors if the ATCOs cannot sleep. In a study on sleepiness and alertness during the night, Porcu et al. (1998) showed that performance of a letter cancellation task decreased in two-hourly intervals at night.

In summary, a great deal of research has been carried out to show the importance of breaks and the influence of night shifts on decreased performance and increased errors. Researchers agree on the point that the night shift has a negative influence on health, and it becomes clear that safety is more compromised at night than during the daytime. It is also apparent that breaks are of paramount importance, especially at night.

Air Traffic Controllers (ATCOs) from the Eurocontrol Maastricht Upper Area Control Centre (MUAC), located in the Netherlands, are responsible for safe and expeditious air traffic coordination for the upper airspace, starting at 24500 feet, of North-West Germany, Belgium, the Netherlands and Luxembourg. At night, they work in two teams, each consisting of two ATCOs. When one team is working, the other team is on break. As their work requires continuous attention, they have to take breaks after a few hours. At night, however, barely any aircraft has to be coordinated in this airspace. The workload does not increase until the early morning hours, starting at 5.00. Initially, one team worked from 0.00 to 4.00, and the other team worked from 23.00 – 0.00 and from 4.00 to 6.30. The ATCOs requested to extend the middle part of the night shift, during which barely any traffic has to be managed, from four hours on position without a break to five hours. In this way, they argued, the complementary team, taking over again at 5.00, would be more refreshed for the final one and a half hours, when traffic increases again and more attention is required.

Even though plenty of research has been conducted in this area, it cannot be deduced which work-break pattern is best for health and safety with only two teams available during 7.5 hours of night shift. Five hours working time at night without any break seems to be risky, while on the other hand, five hours of sleep for the complementary team might lead to a safer performance than four hours. No available study has investigated whether there is any difference at all between working four or five hours at night with next to no traffic. In addition, it has to be considered that the risk in the team commencing five-hour working periods with no break should be balanced by the potential benefits for the complementary team taking over refreshed when traffic increases in the early morning.

Considering that tasks with a low workload – especially when carried out at night – result in a quick reduction of visual attention, it is expected that during night shifts, shift changes after a small number of working hours lead to the best and safest performance. The requested five-hour working time without a break is expected to lead to a stronger decrease in attention than shorter periods of working time. It is also expected that a longer break during the night shift, which allows a proper sleep, will result in better performance. Since this longer break is connected with a longer working period without a break for the team which is taking over during the long break, the advantages and disadvantages of the single work-break patterns during the night shift need to be compared.

Therefore, the objective of the present study was to find out:

1. Whether attention during five hours working on position without a break decreases more than during four hours,
2. Whether attention after five hours of break is better than after four hours of break,
3. Whether the ATCOs are more highly attentive during a specific break pattern than during other break patterns.

To ensure external validity, this study was carried out in MUAC during normal operation at night. For this reason, it was permissible to work different break patterns on a voluntary basis.

METHOD

Subjects

189 ATCOs of MUAC participated in the present study. The study was conducted on randomly chosen nights and participants differed greatly in terms of gender, age and nationality. 126 (83.4%) males and 25 (16.6%) females participated. Their age ranged between 20 and 50 years, with a mean age of 34 (SD=6.296). The ATCOs were of 23 different nationalities, with the highest numbers being German (21.9%), Belgian (18.5%), or British (13.2%). The division into the three patterns was realized according to the shifts.

Break Patterns

Initially, four patterns were suggested for comparison regarding the level of attention in order to identify the safest and healthiest break pattern:

Pattern 1 (5-hour break condition): Working from 23.00 to 24.00 and from 5.00 to 6.30 for one team and from 0.00 to 5.00 for the other team, as was suggested by some controllers.

Pattern 2 (4-hour break condition): Working from 23.00 to 1.00 and from 5.00 to 6.30 for one team, and from 1.00 to 5.00 for the other team, which was common practice.

Pattern 3 (split condition): One team working from 23.00 to 3.00 and the other team taking over from 3.00 to 6.30.

Pattern 4: One team working from 23.00 to 1.00 and from 3.00 to 5.00 and the other team working from 1.00 to 3.00 and from 5.00 to 6.30.

However, the two-hour-condition was not feasible due to a lack of acceptance among the ATCOs and difficulties in the arrangements of sleeping facilities.

Attention test

Because the first three patterns were planned to be tested during normal operation, tests with long duration, which Wilkinson (1969) stated to be sensitive to performance deterioration, were not possible for the present study as they would have presented a risk to safe operation. For safety reasons, it was decided to use a standardized test which required as little time as possible and could be conducted near the working position so that an immediate support for the team-mate left on position was possible when necessary.

Therefore, the attention test *d2* was chosen, which claims to measure continuous attention and to be stable over time. The *d2* consists of 14 lines of d´s and p´s, with one or two lines above and/or below the letters, each line consisting of 47 characters. Within a given time, as many d´s as possible with exactly two lines have to be crossed out. d´s with a different number of lines and all p´s are to be neglected. The test enables the analysis of speed, ambiguity errors (wrongly chosen targets), omissions (targets which should have been chosen but were not) and overall attention level. It was developed for safety in mining, industry and traffic in order to check fitness for work. The stability over time was tested after five hours, and the measures showed a very high correlation (r_{tt} = .89 - .92). The test has been repeated after several months (Brickenkamp & Rupp, 1966 cited after Brickenkamp, 1981; Büttner, 1968 cited after Brickenkamp, 1981), showing a high test-retest reliability.

Participants are told how to fill out the test and are instructed to practice their understanding with a training line. If there are any mistakes in the training line, these are corrected by the instructor and further questions of the participant are clarified. Since the instructors of the present study completed almost every line within the usual 20 seconds, it was decided to allow only 15 seconds for the controllers in order to avoid a ceiling effect; an option which was already suggested in the manual (Brickenkamp, 1991).

Due to the convenient and quick application, the resistance to distortion and the high stability over time, after thorough research, the *d2* seemed to be a good choice for measuring continuous alertness as a closely related construct to vigilance (Zimmermann & Fimm, 2009).

Subjective Sleepiness

The objective measurement of alertness is complemented by a subjective opinion of the controllers in order to gain information about their perceived well-being. The *Stanford Sleepiness Scale* (SSS) provides the possibility to rate the subjective perception of sleepiness.

Additional Variables

In addition to these two tests, the participants filled in a questionnaire with demographic data, questions on their current fitness, sleep before and during the night shift, and their opinion on the organization of the night shifts used in this study. To be able to allocate the results of the different measures anonymously for each controller, the mother code, a combination of four defined letters of the last and maiden name of their mother, was used.

Field Study Design

Three measurements of attention and perceived sleepiness were carried out during the night shift at MUAC with the scheduled ATCOs, and one comparative measurement was undertaken during the day shift with the same participants. At the beginning of the night shift, the background of the study was explained to every ATCO individually, and the first part of the questionnaire was filled in. Afterwards, participants were asked to rate their sleepiness on the SSS, followed by the *d2*. The *d2* was explained and practiced before it was tested using 15 seconds for each line. According to the assigned pattern, the next measure was taken after a defined time (see table 1), consisting of the SSS and the *d2*. Usually, no additional explanation and training was necessary. At the end of the shift, the SSS and the *d2* were completed again and the final questionnaire was handed out.

The times of measurement were defined before the study for each of the two pairs of ATCOs in the three patterns. The first team (team A) of pattern 1 (5-hour pattern) was tested at 23.00, and team B was tested at 24.00, 2.00 and 4.30; team A was tested again at 5.00 and 6.00. For pattern 2 (4-hour pattern), team A was tested at 23.00 and team B was tested at 1.00, 3.00 and 4.30; team A was then tested again at 5.00 and 6.00. For pattern 3 (split night), team A was tested at 23.00, 1.30 and 2.30; team B then took over and was tested at 3.00, 4.30 and 6.00.

Table 1: Overview of the time of measurements for all three patterns

Time	Pattern 1	Pattern 2	Pattern 3
23.00	Team A	Team A	Team A
24.00	Team B		
1.00		Team B	
1.30			Team A
2.00	Team B		
2.30			Team A
3.00		Team B	Team B
4.30	Team B	Team B	Team B
5.00	Team A	Team A	
6.00	Team A	Team A	Team B

Note: Team A and team B both consist of two ATCOs, who are working together on one position at the same time. While team A is working, team B is on break and vice versa.

After finishing all night shift measurements, each participant was tested again during a regular day shift in which they filled in the SSS and the *d2*.

RESULTS

Attention test d2

The results of the *d2* show that attention decreases during the night shift, with one exception for pattern 2 part 1 from the second measurement (at 5.00 a.m.) to the third measurement (at 6.00 a.m.). However, this minor improvement is not significant.

A repeated measures ANOVA showed a main effect of time, with $F(2,186) = 13.491$, $p < 0.001$, while no difference could be found for the three different break patterns. The pairwise comparisons of the means were significantly different between time 1 and time 2 ($p < 0.05$) and between time 1 and time 3 ($p < 0.001$). This means that attention decreases in all patterns, regardless of the possibility of sleep for the first part of patterns 1 and 2, and irrespective of whether the ATCOs have worked four hours without a break or five hours without a break.

Table 2: Overview of the results across the three measures for the 6 conditions and the patterns overall

		N	Time 1		Time 2		Time 3	
			M	SD	M	SD	M	SD
Pattern 1	Part 1	23	150.35	18.53	144.13	26.24	143.57	29.04
	Part2	31	162.45	44.27	161.47	54.14	152. 86	39.20
	Overall	54	157.30	35.89	154.08	44.94	148.90	35.23
Pattern 2	Part 1	29	162.83	31.26	155.96	36.58	158.60	38.71
	Part2	28	151.50	32.51	143.67	28.53	142.12	34.78
	Overall	57	152.26	32.10	149.92	33.16	150.51	37.43
Pattern 3	Part 1	39	155.05	29.22	146.51	28.29	137.79	27.33
	Part2	39	149.74	37.95	144.31	31.43	140.54	31.60
	Overall	78	152.40	33.75	145.41	29.73	139.17	29.38
Total		189	155.26	33.80	149.25	35.66	145.37	33.90

Note: Part 1is the part of the specific break pattern that is worked by team A, while part 2 is the second part of the break pattern, which is worked by team B. For patterns 1 and 2, this means that part 1 is the beginning and end of the night shift, whereas part 2 is in the middle; for pattern 3, part 1 is the first half of the night shift from 23.00 until 3.00 and part 2 the second part of the night shift from 3.00 to 6.30.

Subjective Sleepiness

A comparison of the single measures of the d2 with the SSS resulted in a moderate negative correlation (r_{t1} = -.278; r_{t2} = -.158; r_{t3} = -.172). This means that the more sleepiness is perceived by the ATCOs, the more the level of attention decreases.

A repeated measures ANOVA for the SSS showed, similar to the results of the *d2*, a main effect of time, with $F(2,186) = 42.931$, $p < .001$; no main effect was found for the three break patterns. The subjective perceived sleepiness significantly decreases from the first measurement (M = 2.61, SD = .97) to the second (M = 3.10, SD = .99) and to the third (M = 3.33, SD = 1.10) with $p < 0.001$, and from the second measurement to the third with $p < 0.05$.

Additional Variables

Since the standard deviation is rather high in all patterns during all three measurements, the results of the *d2* were compared with the age of the participants. At r = - .28, the correlation shows that with increasing age, the level of attention decreases.

The sleeping time before and during the night shift was not comparable. Due to the fact that the previous shift had also been finished at different times, this information could not be used for further explanation.

The question of which break pattern was preferred by the ATCOs revealed no unambiguous preference. There was no association between the pattern they had worked on the night when they were tested and the pattern they preferred.

DISCUSSION

It was assumed that five hours of working without a break would lead to a larger decrease in attention than four hours without a break, and that one particular break pattern would be the best with regard to attention. None of these hypotheses can be sustained.

Since this study was carried out during normal operation in the field, a systematic control of potential confounding variables was restricted. For example, it was not possible to influence the workload, noise or preparation time. It was solely feasible to allocate the ATCOs to the three different break patterns so that the groups were of comparable size. Therefore, the internal validity is rather low: The ATCOs differed in their sleeping time before their shift, in the time since they had worked their last shift, in their sleeping quality during the day and in the way they used their break – some went for a sleep, while others worked at the computer. A few ATCOs had to deal with unexpected situations like organizing an emergency landing, which might have increased their arousal. Different weather conditions put some controllers under high pressure at the beginning of the night, whereas others were already able to calm down for the anticipated sleep after a short while.

The fact that no differences between the three patterns were significant can also be explained by the general different levels of attention of the participants. As can be seen in table 2, the results deviate to a large extent from the means for all patterns during all three measures; indeed, not even the results for the first measure in the different patterns, which was always conducted at the same time, are comparable. In addition, the age of the participants differs with a range of 30 years. Since the level of attention changes with age, this might be one of the reasons for the high standard deviation. A comparison of the attention results with age supports this assumption, with r = -.28.

In future research, these single variables should be considered under controlled laboratory conditions.

The external validity, however, is reasonably high. The study was conducted during normal working conditions, meaning that the different weather or shift conditions, as well as the different habits of the ATCOs before and during the night shift, can be seen as representative for the field.

Even though the individually varying difference in the level of attention resulted in such a high standard deviation that it was hardly possible to gain statistically significant results, precisely these differences are common in the field. ATCOs get older, and they differ individually, meaning that these highly deviating results can be regarded as representative.

Since the external validity can be regarded as given, it is possible to derive practical implications for work-break patterns. However, these implications might be restricted to ATCOs, for whom one of the most important skills is to be highly attentive for a longer period of time. The results in the applied attention test are higher than of those occupational groups that were tested for the normalization of the results of the *d2*. An accurate comparison was not possible, as the normalization was only based on the usual 20 seconds for each line. No comparison data for the alternative 15 seconds per line were available. However, a closer look at the single tests sustains the assumption that 20 seconds per line would have led to a ceiling effect for ATCOs.

For ATCOs working on the radar, different break patterns do not seem to have an influence on their attention skills. Presumably, they have learned during their professional experience how to cope with fatigue such that their attention is not decremented by longer working periods. Due to the fact that attention decreases with subsequent working hours during the night and that the subjective perceived fatigue is linked to a lack of attention (r = -.28), it is nonetheless recommended to organize night shifts that are as short as possible for the individual ATCOs.

However, further research is still necessary in order to provide recommendations for how a night shift with a restricted number of working ATCOs should be designed to ensure a healthy and safe operation.

ACKNOWLEDGEMENTS

The authors would like to thank Eurocontrol Maastricht for enabling this study financially and by allowing the changes in the night shifts. In addition, we would like to thank all participating ATCOs for their collaboration.

REFERENCES

Brickenkamp, R. (1991). *Test d2 – Aufmerksamkeits-Belastungs-Test [Test d2 – Test of Continuous Attention]*. Göttingen: Hogrefe.

Costa, G., Lievore, F., Casaletti, G., Gaffuri, E. & Folkard, S. (1989). Circadian characteristics influencing interindividual differences in tolerance and adjustment to shiftwork. *Ergonomics, 32(4)*, 373 – 385.

Dahlgren, K. (1981). Adjustment of Circadian Rhythms and EEG Sleep Functions to Day and Night Sleep Among Permanent Nightworkers and Rotating Shiftworkers. *Psychophysiology, 18(4)*, 381 –391.

Dinges, D.F. (1995). An overview of sleepiness and accidents. *Journal of Sleep Research, 4*, 4 – 14.

EATM (2006). *Managing Shiftwork in European ATM: Literature Review.* Brussels: Eurocontrol.

Folkard, S. & Condon, R. (1987). Night shift paralysis in air traffic control officers. *Ergonomics, 30(9)*, 1353 -1363.

Folkard, S., Lombardi, D.A., Tucker, P.T. (2005). Shiftwork: Safety, Sleepiness and Sleep. *Industrial Health, 43*, 20 – 23.

Folkard, S. & Tucker, P. (2003). Shift work, safety and productivity. *Occupational Medicine,* 53(2), 95 – 101.

Folkard, S. (1992). Is there a "best compromise" shift system? *Ergonomics, 35(12)*, 1453 – 1463.

Gold, D.R., Rogacz, S., Bock, N., Tosteson, T.D., Baum, T.M., Speizer, F.E. & Czeisler, C.A. (1992). Rotating Shift Work, Sleep, and Accident Related to Sleepiness in Hospital Nurses. *American Journal of Public Health*, 82(7), 1011 – 1014.

Hahn, 1988 in EATM (2006). *Managing Shiftwork in European ATM: Literature Review.* Brussels: Eurocontrol.

Hopkin, D. (1995). *Human Factors in Air Traffic Control*. London: Taylor & Francis.

Larue, G.S., Rakotonirainy, A., Pettitt, A.N.(2010). Real-time performance modelling of a Sustained Attention to Response Task. *Ergonomics, 53(10)*, 1205 – 1216.

Leonard, D., Fanning, N., Attwood, J. & Buckley, M. (1998). The Effect of Fatigue, Sleep Deprivation and Onerous Working Hours on the Physical and Mental Wellbeing of Pre-Registration House Officers. *Effects of doctors´ long working hours, 167(1)*, 22 – 25.

MacLean, K.A., Aichele, S.R., Bridwell, D.A., Mangun, G.R., Wojciulik, E., Saron, C.D. (2009). Interaction between endogenous and exogenous attention during vigilance. *Attention, Perception & Psychophysics, 71(5)*, 1042-1058.

Monk, T.H. (1986). Advantages and Disadvantages of Rapidly Rotating Shift Schedules – A Circadian Viewpoint. *Human Factors, 28(5)*, 553 – 557.

Monk, T.H.; Folkard, S. & Wedderburn, A.I. (1996). Maintaining safety and high performance on shiftwork. *Applied Ergonomics, 27*, 17 – 23.

Pilcher, J.J.; Band, D.; Odle-Dusseau, H.N.; Muth, E.R. (2007).Human Performance Under Sustained Operations and Acute Sleep Deprivation Conditions: Toward a Model of Controlled Attention. *Aviation, Space, and Environmental Medicine, 71(5)*, B15-B24.

Porcu, S., Bellatreccia, A., Ferrara, M., Casagrande, M. (1998). Sleepiness, alertness and performance during a laboratory simulation of an acute shift of the wake-sleep cycle. *Ergonomics, 41(8)*, 1192 – 1202.

Purnell, M.T., Feyer, A.M. & Herbison, G.P. (2002). The impact of a nap opportunity during the night shift on the performance and alertness of 12-h shift workers. *Journal of Sleep Research, 11*, 219 – 227.

Rocco, P.S.D., Comperatore, C., Caldwell, L., Cruz, C. (2000). *The Effects of Napping on Night Shift Performance*. Washington: Federal Aviation Administration.

Rosekind, M.R., Gander, P.H., Miller, D.L., Gregory, K.B., Smith, R.M., Weldon, K.J., Co, E.L., McNally, K.L & Lebacoz, J.V. (1994). Fatigue in Operational Settings: Examples from the Aviation Environment. *Human Factors, 36(2)*, 327 – 338.

Szalma, J.L., Warm, J.S., Matthews, G., Dember, W.N., Weiler, E.M., Meier, A., Eggemeier, F.T. (2004). Effects of Sensory Modality and Task Duration on Performance, Workload, and Stress in Sustained Attention. *Human Factors, 46*, 219-233.

Thiffault, P. & Bergeron, J. (2003). Monotony of road environment and driver fatigue: a simulator study. *Accident Analysis and Prevention, 35*, 381 – 391.

Touitou, Y., Motohashi, Y., Reinberg, A., Touitou, C., Bordeleau, P., Bogdan, A. & Auzéby, A. (1990). Effect of shift work on the night-time secretory patterns of melatonin, prolactin, cortisol and testosterone. *European Journal of Applied Physiology, 60(4)*, 288-292.

Weinger, M.B. (1999). Vigilance, Boredom and Sleepiness. *Clinical Minitutorial, 15*, 549 – 552.

Wilkinson, R.T. (1969). Some factors influencing the effect of environmental stressors upon performance. *Psychological Bulletin, 72*, 260 – 272.

Zimmermann, P. & Fimm, B. (2009). *TAP – Testbatterie zur Aufmerksamkeitsprüfung [TAP – Test Battery for Attentional Performance]*. Herzogenrath: Psytest.