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ORIGINAL RESEARCH

All night long: an assessment of the cognitive effects of night shift work in anaesthesiology trainees

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Background: Excessive working hours and fatigue in medical training are a source of concern. Practitioner fatigue manifests itself in both risks to the patient and the medical trainee. This study aimed to quantify the effect of shift work on multiple cognitive function domains in anaesthesiology trainees at Tygerberg Academic Hospital. Secondary outcomes were to identify strategies to ameliorate shift work-related fatigue.
Methods: An analytical observational study was conducted using mixed methods. The participants, anaesthesiology registrars and medical officers, completed an electronic cognitive test battery consisting of four tests, and a paper-based questionnaire prior to and following a 14-hour night shift.
Results: Twenty-nine participants engaged in the study; including 14 males and 15 females with an age range 29–58 years. The study demonstrated a statistically significant impairment in reaction time in two of the four cognitive domains tested, ranging from 13.4–17.8%. No statistically significant change in accuracy was seen in any of the cognitive tests. A subjective increase in fatigue was also demonstrated using the Karolinska Sleepiness Scale. Further, no statistically significant correlation was found between the decline in reaction time and the individual and work-related factors which were assessed in the paper-based questionnaires.
Conclusion: Fatigue in anaesthesiology trainees after a 14-hour night shift results in a decline in reaction time in the cognitive domains of psychomotor function and attention. Accuracy, however, remained unchanged. The study was unable to identify strategies which ameliorated these effects with statistical significance. Nevertheless, the recommendations and guidelines of various anaesthesiology bodies, including the South African Society of Anaesthesiologists, are supported. Further studies using a larger and more diverse study population are suggested.

Keywords: fatigue, cognitive function, medical trainee, shift work, reaction time

Introduction

Sleep, although poorly understood in its function, is important in maintaining cognitive and psychomotor abilities.[1] Insufficient sleep is becoming more prevalent and has been labelled by the Centers for Disease Control and Prevention in the United States as a public health problem.[2] This increase in prevalence is associated with a twenty-four hour modern society.[2] However, the impacts are most notable and relevant in industries which require an uninterrupted service, such as industrial production, transportation and public safety.[3] These impacts become even more critical in operations which require high level cognitive performance, including healthcare and the military.[3]

Excessive working hours and fatigue in medical training have been a source of increasing concern.[4,5] In the South African context, the South African Society of Anaesthesiologists provided a position statement on workload and fatigue as part of their Practice Guidelines 2018 Revision. This statement was in response to concerns raised about the working conditions of junior doctors and trainees in the public health setting.[6] The recommendations from these guidelines are that continuous on-call duty of less than 12.5 hours is suggested, more than 17 hours should be discouraged and excess of 24 hours should be condemned.[6] Further, consecutive duties should allow for an adequate rest period in proportion to the hours worked. However, even these guidelines highlight that these recommendations and suggestive corrective strategies are often disregarded in the supposed interest of patient care and that the information available in this arena is limited.[6] Therefore, solutions for managing the problem in the public sector in South Africa remain elusive.

The aims and primary outcome of this study were firstly to quantify the impact that shift work has on multiple domains of cognitive function in anaesthesiology trainees at Tygerberg Academic Hospital. This was evaluated using both subjective and objective measurement tools. A secondary outcome was to identify strategies to ameliorate the effects of shift work-related fatigue.

Methods

This was an analytical observational study, in which each participant was assessed prior to and following the completion of a 14-hour night shift. Each participant completed a written questionnaire and a battery of cognitive tests which were administered on a personal laptop computer and data were captured electronically.

After ethical approval from the Stellenbosch University Health Research Ethics Committee was obtained (S18/06/131), all anaesthesiology trainees, including postgraduate registrars and medical officers, in the service of the Department of Anaesthesiology and Critical Care at Tygerberg Academic Hospital were invited to participate in this study, with the exception of the primary investigator. Forty-four individuals were eligible for participation, of which 29 completed the study.

Each participant completed a process of informed consent and was allocated a study number so as to de-identify their test results and other data. Testing began with the completion of a written questionnaire. The questionnaire included demographic data, the Karolinska Sleepiness Scale as a subjective measure of fatigue, an assessment of activities on the day preceding the night shift and information regarding the number of night duties completed in the week preceding the night of testing. The Karolinska Sleepiness Scale is demonstrated in Figure 1.

1. Extremely alert
2. Very alert
3. Alert
4. Rather alert
5. Neither alert nor sleepy
6. Some signs of sleepiness
7. Sleepy, but no effort to keep awake
8. Sleepy, some effort to keep awake
9. Very sleepy, great effort to keep awake, fighting sleep

Figure 1: Karolinska Sleepiness Scale[7]

The battery of cognitive tests then proceeded. The computerised test battery software was provided by Cogstate®. Cogstate® is a cognitive science company based in the United States of America. They design computerised cognitive tests to be used commercially and at the time of this study they provided these test batteries without charge to those undertaking academic research with affiliation to a university or other recognised body. The battery can be customised to suit the requirements of the study and the specific tests which were used in this study were selected by the primary researcher.

Four tests were included in the cognitive test battery and all used a playing card interface. Each test focussed on a particular cognitive domain and the response from the participant was measured in terms of both speed and accuracy. The tests used are described in Table I. Each test continued for approximately four minutes and required the participant to use the mouse to click right for a 'yes' response and left for a 'no' response.

The same cognitive test was then performed after the completion of the 14-hour night shift, which ran from 17:00 to 07:00. This was also accompanied by a paper-based questionnaire, which included the Karolinska Sleepiness Scale; an assessment of whether the participant had opportunity to rest during their shift; and a subjective assessment of the difficulty of the shift. Both questionnaires used before and after the night shift were designed by the author. (See Appendix A and B.)

In the process of data analysis, the Biostatistics Unit at the Faculty of Medicine and Health Sciences, University of Stellenbosch, were consulted and their participation was integral to collection, management and statistical analysis of the data.

IBM SPSS version 25 was used to analyse the data. A *p*-value < 0.05 indicated statistical significance. Paired t testing and repeated measures analysis of variance testing was used to compare the data obtained from the cognitive tests performed prior to and following a night shift. Factors in the model included gender, age, use of stimulants and behavioural factors, such as pre-call activities and pre-call naps. A full factorial model was used. The effect of time was the main exposure of interest, whilst interactions between time and the various factors indicated significant confounding.

Results

A description of the demographics and experience of the 29 participants in the study is summarised in the accompanying Table II. Experience is described both in terms of general anaesthesiology exposure as well as duration of experience at Tygerberg Academic Hospital.

Table II: Participant demographics and experience

Age	Median (years)	Interquartile range (IQR) (years)
	33	32–34
Gender	**Male**	**Female**
	14 (48.3%)	15 (51.7%)
Experience	**Median (months)**	**IQR (months)**
Anaesthesiology	27	14–48
Tygerberg Academic Hospital	48	36–66

Table I: Details of cognitive tests

Test	Description
Detection	Participant presented with a playing card face down. When the card flipped over, use the mouse to click 'yes' as quickly as possible. Measured processing speed using a simple reaction time paradigm. Cognitive domain assessed: psychomotor function.
Identification	Playing card presented face down again. When the card flipped over, the participant was expected to decide if the card was red. If the card was red, the participant clicked 'yes', if the card was black, the participant clicked 'no'. Measured attention using a choice reaction time paradigm. Cognitive domain assessed: attention.
One card learning	Participant was shown a series of playing cards. For each card, the participant had to decide if they had seen the card before during the test. They then clicked 'yes' or 'no' accordingly. Measured visual memory using a pattern separation paradigm. Cognitive domain assessed: visual learning.
One back speed	Participant was shown a series of playing cards. For each card, the participant had to decide if the card was the same as the previous card; and clicked 'yes' or 'no' accordingly. Measured working memory using an n-back paradigm. Cognitive domain assessed: working memory.

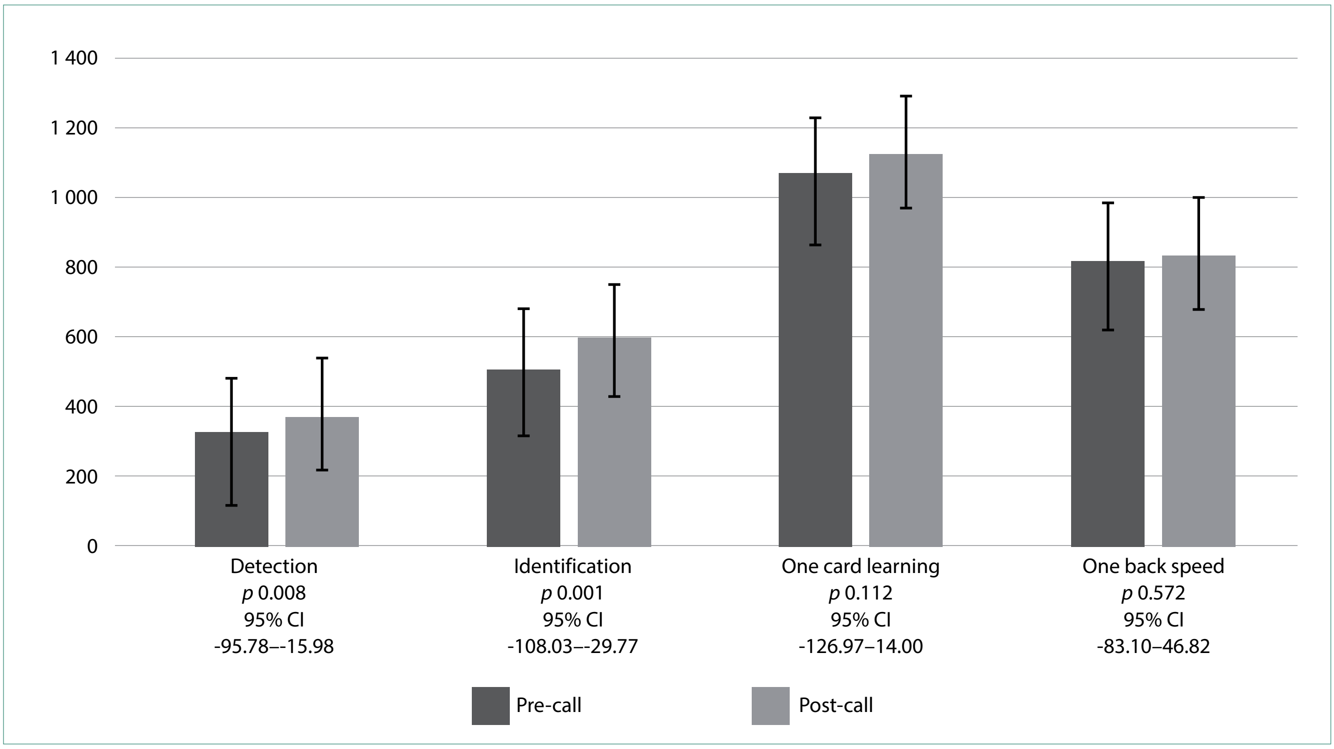

Figure 2: Mean response times by test (ms). Error bar indicates standard error of the mean. *p* – *p*-value indicates significance of difference between post- and pre-call testing. 95% CI – 95% confidence interval of the difference between post- and pre-call testing

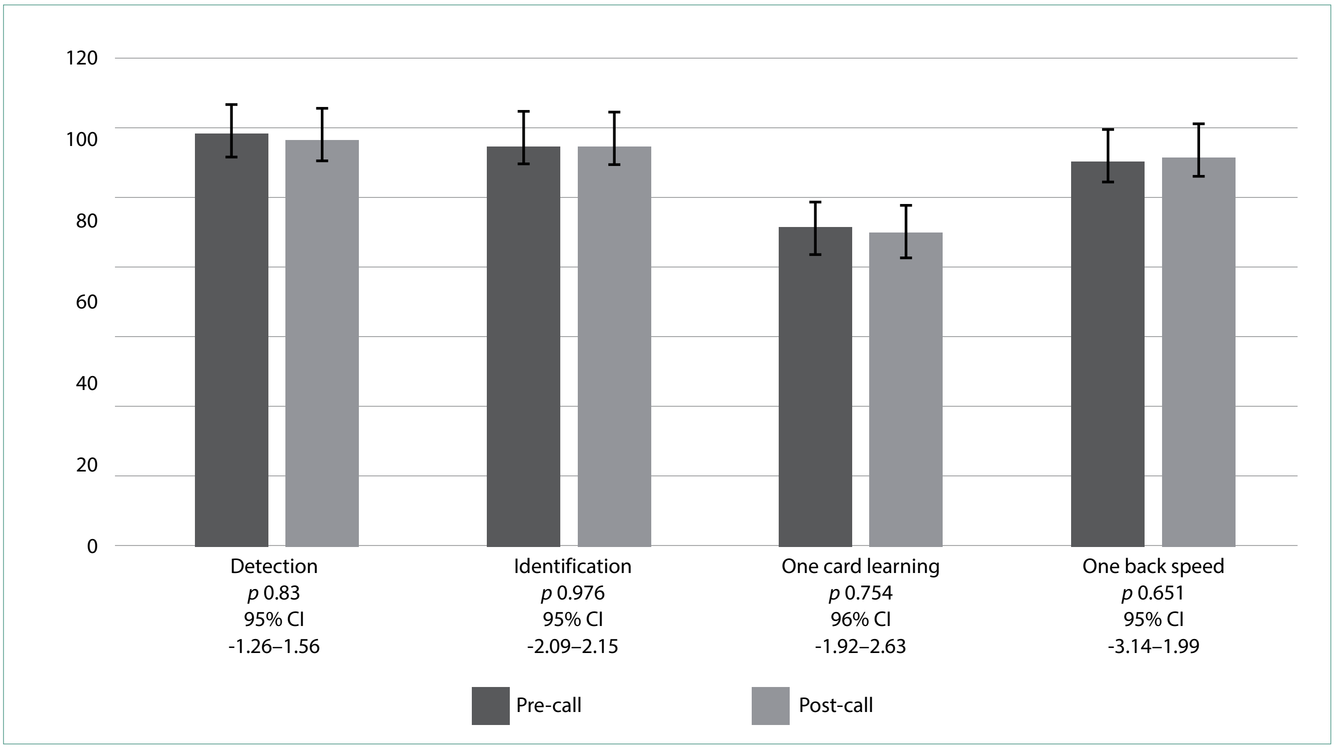

Figure 3. Accuracy by test (%). Error bar indicates standard error of the mean. *p* – *p*-value indicates significance of difference between post- and pre-call testing. 95% CI – 95% confidence interval of the difference between post- and pre-call testing

The primary outcome of impact of shift work on cognitive function was assessed in two manners, in that both speed and accuracy were measured.

Speed of response showed a decline from pre- to post-call testing in all four tests administered. This decline was statistically significant ($p < 0.05$) in the *detection* and *identification* tests. In these tests this decline was denoted by a mean difference in reaction speed of 55.88 ms (standard deviation [SD] 96.67) and 68.9 ms (SD 102.87) respectively. Although the *one card learning* and *one back speed* tests did show an absolute mean decline in speed of 56.48 ms (SD 185.31) and 18.14 ms (SD 170.78) respectively, this was not found to be statistically significant.

The accuracy with which all four tests were completed showed no significant difference between pre-call and post-call test-ing. Both accuracy and speed results are denoted in Figures 2 and 3.

Secondary outcomes were sought by searching for associations between the primary tests which showed statistically significant changes and the participants' questionnaire answers. Therefore, associations were only pursued in relation to reaction speed for two of the tests; namely *detection* and *identification*.

Associations were assessed by multivariate analysis of variance testing and were considered significant if the Wilk's lambda test showed a significant value with $p < 0.05$, as previously stated. The variables considered were all those which participants answered to in the pre- and post-call questionnaires. These were: gender; age; marital status; activities partaken on pre-call day; napping on pre-call day; use of stimulants (e.g. caffeine) on pre-call day and during night shift; number of night shifts in preceding week; level of experience in anaesthesia and at Tygerberg Academic Hospital; pre- and post-call self-assessment of fatigue using the Karolinska Sleepiness Scale; duration of breaks and sleep during night shift if any; and self-assessment of night shift difficulty on a Likert-type scale. Using this method, no statistically significant correlations with deterioration in reaction time were found.

Subjective assessment of fatigue using the Karolinska Sleepiness Scale did demonstrate a perceived decline in wakefulness by participants. The median score on this scale had a statistically significant increase from 3 to 6 using the Wilcoxon signed-rank test ($p < 0.001$), with a large effect size, denoted by a ranked pairs matched biserial correlation of 1. However, this did not have statistical correlation with the objective cognitive test battery.

Sustained wakefulness of greater than 17 hours can be ascer-tained to have occurred in 10.3% of the participants in this study. These participants reported having no pre-call nap, as well as no sleep during their night shift. Other participants may have been exposed to a similar period of wakefulness, but as the time of pre-call naps was not obtained in the questionnaire, this could not be confirmed.

Discussion

After a 14-hour night shift, cognitive testing in anaesthesiology trainees at Tygerberg Academic Hospital demonstrated a statistically significant decline in response time in tests of the following cognitive domains: psychomotor function and at-tention. However, response time in testing of the domains of visual learning and working memory showed no such significant change. Further, the participants showed no change in accuracy in any of the testing domains.

This speed-accuracy trade off, where speed of response is fore-gone in order to maintain accuracy or vice versa, is an example of heuristics or mental shortcuts.[8] Heuristics are cognitive strategies used in decision making to obtain adequate solutions while minimising systematic processing, and may be more prevalent in the setting of fatigue.[8] The choice of whether to forego speed or accuracy is determined by circumstance and what is perceived by the individual to maximise reward rate.[9]

In this study, the decline in response speed ranged from 13.4–17.8%, dependent on the cognitive domain being tested. The affected cognitive domains, in this study, were psychomotor function and attention. Both these domains constitute a large part of the characteristics of the workload during anaesthesia. Attention or vigilance may be defined as 'the ability to remain alertly watchful especially to avoid danger'.[10] While psychomotor function, the relationship between cognitive function and phys-ical movement, is demonstrated through tasks such as dexterity, tracking and reaction time.[10] Other studies investigating decline in cognitive performance related to fatigue and sustained wakefulness in medical trainees have shown similar declines in speed, ranging from 4.64–40%.[4,11,12] These studies have varying study design and used an array of cognitive tests.

It is important to note, that studies have shown that sustained wakefulness of more than 17 hours has a similar impact on psychomotor performance as a blood alcohol concentration of 0.05%.[4,6,12-16] This is equal to the legal driving limit for blood alcohol concentration in South Africa[17] and such a period of wakefulness could be confirmed in 10.3% of the participants in this study. As such, using alcohol as a comparator in this study, may have provided an interesting qualitative parallel with which to assess the decline in response times seen here due to the fatigue associated with night shift work and prolonged wakefulness. Even the World Health Organization recommends that the behavioural effects of drugs can be measured using alcohol as a comparison.[18] However, in order to correlate alcohol intoxication with fatigue, one would further have to consider intra-individual and within-group variability of response to al-cohol intoxication.[19] This is an interesting avenue to pursue in further studies of fatigue in medical registrars and medical officers.

The impact of fatigue, which has been demonstrated in this study by a decline in reaction speed in two cognitive domains, manifests itself in both risks to the patient and the medical trainee. It has been demonstrated that drug errors are four times more likely to occur when the medical trainee is fatigued.[13] Epidurals placed at night are six times more likely to result in unintentional dural puncture than those placed during the day.[13] Needlestick injuries increase between three- to five-fold at night time across various disciplines.[13] Medical trainees are twice as likely to be involved in a road traffic accident than the general population.[13,15] This is particularly concerning as 93.1% of participants in this study planned to drive themselves home after completing their night shift. While only 6.89% would have rested at work before driving home. In addition, consideration must also be given to the 'second victim' effect, when an error that results in patient harm, leads to devastating psychological consequences for the trainee.[20]

Up to 86% of medical trainees responding to survey studies have reported committing a medical error where they attribute fatigue as a causative factor.[10,13] This is despite the limitation placed on the trainee's ability to judge their own level of impairment, as self-awareness is reduced in the setting of fatigue.[4,13] Trainees have also reported adaptation to the effects of chronic sleep loss as their experience increases.[4] However, studies have shown no objective evidence that such acclimatisation exists, and no association was found in this study between age or experience and improved outcomes.[4,12] Self-assessment of cognitive performance is often based on the management of critical tasks, but such tasks are associated with arousal which may overcome fatigue-induced cognitive impairment. Therefore, trainees who base the assessment of their own fatigue on their management of clinical crises, will likely overestimate their abilities.[12] This is, again, in keeping with this study's finding that the majority of participants planned to drive home despite subjectively perceiving a decline in wakefulness.

This study also attempted to identify strategies to ameliorate fatigue-induced effects on cognition. Participants were questioned both before and after their night shift. Prior to the call, participants were asked to submit the following information: demographic information; activities partaken in; napping pre-call; stimulant use; number of recent calls; length of experience in anaesthesiology and at Tygerberg Academic Hospital; and a subjective fatigue assessment. Post-call questions included: opportunity for breaks and sleeping on shift; stimulant use; self-assessment of call difficulty and fatigue.

No statistically significant correlations were found between these factors and deterioration in cognitive function after a night shift. Surprisingly, this includes no significant correlation with experience or self-assessment of fatigue. This study can therefore make no evidence-based recommendations regarding lifestyle changes for the individual or institutional changes for the organisational structures involved, in order to improve night shift work-related fatigue in this population.

However, the preventive and corrective strategies recommended by the South African Society of Anaesthesiologists must be supported in this regard.[6] These were based on a series of studies on the impact of long work hours on healthcare providers and patients including the work of Lockley et al.[21] The guidelines include:

- Daytime sleeps before a night shift.
- Naps of at least 40 minutes when excessively fatigued and prior to driving home.
- Improved structure of call and shift rosters.
- Caffeine consumption improves alertness but may impair rest and nap breaks.
- Continuous on-call duty of less than 12.5 hours is suggested, more than 17 hours is to be discouraged, and excess of 24 hours is to be condemned when the main activity is provision of anaesthesia.
- Work schedule must provide for non-clinical activities.
- Scheduling plan to ensure availability and appropriate supervision of junior providers.
- Equipment checking discipline.
- Adequate personnel to workload ratios.[6]

Several international anaesthesiology bodies have also published guidelines and recommendations regarding fatigue and the anaesthesiologist. The Association of Anaesthetists of Great Britain and Ireland have recommendations which include that job plans should be constructed such that they are not likely to lead to predictable fatigue.[22] They also highlight individual strategies to reduce and mitigate the effects of fatigue, such as good sleep hygiene.[22] The Australian and New Zealand College of Anaesthetists have guidelines which suggest that anaesthesiologist working time should not exceed 12 hours and where this is not feasible, due to staffing or hospital coverage requirements, shift duration should be kept below 16 hours.[23] The World Federation of Societies of Anaesthesiologists, in collaboration with the World Health Organization, recommend that 'a sufficient number of trained anaesthesia providers should be available so that individuals may practice to a high standard without undue fatigue or physical demands'.[24] As well as recommending that 'time should be allocated for education, professional development, administration, research and teaching'.[24]

Certain limitations were present in the undertaking of this study. The population used had a sample size of only 29 participants. As such the study was underpowered to establish important differences, particularly in identifying effective strategies to modify post-call fatigue, in order to make evidence-based recommendations. Using a control group in the study design and considering a non-medical cohort may also have been desirable. These shortcomings should be weighed in the design of future similar studies.

Further, this sample was taken from a single tertiary academic centre, focussed on the speciality of anaesthesiology only and specifically included 14-hour night shifts while other call types were excluded. A wider diversity of specialities and call types at a variety of training centres would have provided a broader perspective of the problem of fatigue in medical trainees.

This study highlights that in providing quality health care to our patients, which remains paramount, we must not lose sight of the importance of maintaining practitioner well-being. As diurnal creatures, the provision of uninterrupted emergency healthcare services will always create obstacles to healthcare providers. However, strategies to minimise the risks associated with practitioner fatigue can be instituted at the individual and organisational level, with adequate staffing being a pre-eminent factor in this resource-limited setting.

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Conflict of interest

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in the writing of this paper.

Ethical approval

Ethical approval was obtained from the Stellenbosch University Health Research Ethics Committee (S18/06/131).

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Appendices available online.