Fatal monotony: Increased daytime sleepiness in the deployed setting

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ABSTRACT

Introduction

Intolerance of monotony, i.e. the tendency to make errors or even fall asleep during monotonous activities, can be life threatening in certain occupational settings. This applies, for example, to drivers, pilots and guards. Combined with the usual types of deployment-related stress, deployments to crisis areas with a high potential of conflict lead to increased daytime sleepiness. Non-physiological shift work schedules with sometimes irregular rest periods, temporary accommodations that are associated with further factors adversely affecting sleep (heat, noise, insects, etc.), and personal worries trigger monotony intolerance and can become a problem for the German Armed Forces. The primary objective of this study was to identify mobile tests for diagnosing monotony intolerance with sufficient sensitivity and specificity and for screening military personnel in a deployed setting.

Material and Methods

The study used an experimental design and included a literature search. The vigilance of 30 subjects (night duty nursing staff of the Bundeswehr Hospital in Hamburg) was assessed before and after a night shift.

Therefor several tests were used: the vigilance test described by Quatember and Maly (VIGIL®), the WAFV, which is a component of the SLEEP® test battery described by Schuhfried (for visual vigilance), the pupillographic sleepiness test (pupillography), the Schuhfried's SLEEP® test (for measuring tonic and phasic central nervous system activation) and the Stanford Sleepiness Scale (SSS) (for assessing sleepiness).
Results
VIGIL® and WAFV – unlike pupillography, the measurement of tonic and phasic alertness, and the SSS – were found to be suitable tests for detecting monotony intolerance with very high levels of sensitivity and specificity. Psychometric tests showed that, after night shift work, 60% of the subjects did not have the level of vigilance required to drive a car, for example. There was a considerable difference between subjective sleepiness and objective test results. Two thirds of the subjects had a higher level of sleepiness than they realized.
Conclusions
VIGIL® and WAFV are two inexpensive computer-based test systems that are easy to operate by even inexperienced users and showed the highest levels of specificity and sensitivity for measuring monotony intolerance. The tests do not require complex hardware and software components (only a portable computer) or special user training. They are suitable for measurements during deployments abroad.
Keywords:
Monotony intolerance, daytime sleepiness, central nervous system activation, sustained attention, sleep deprivation.

1. INTRODUCTION

Daytime sleepiness can have life-threatening consequences. Numerous studies have proven that in Germany, drowsy drivers are involved in more fatal accidents than drunk drivers. As many as 25 % of all fatal accidents on Bavarian motorways are the result of fatigue (Langwieder et al. 1994). Other studies and surveys carried out on road accident casualties also show that fatigue behind the wheel is the most common – and avoidable – cause of accidents (Åkerstedt T 2000, ten Thoren & Gundel 2003, Yamasaki et al. 2016). In Germany, the cost of accidents resulting from fatigue amount to approximately ten billion euros (Hajak & Zulley 2008). A number of disasters have been connected to workplace errors as a result of daytime sleepiness. Examples include the Chernobyl and Three Mile Island reactor accidents of 1986 and 1979, respectively, and the Bhopal gas disaster in 1984. The Exxon Valdez oil spill (1989) and the capsizing of the MS Herald of Free Enterprise ferry after leaving the port of Zeebrugge (1987) were also attributed to fatigue-related human error based on the timing of the accidents (each one happened in the early morning hours) and the circumstances surrounding them (Hajak & Zulley 2008). A Swedish study by the stress researcher Åkerstedt of the University of Stockholm showed that 7 % of employees unintentionally fall asleep at work at least once a month and that as many as 23 % do so during their leisure time (Åkerstedt et al. 2002).

The German Sleep Society (*Deutsche Gesellschaft für Schlafforschung und Schlafmedizin*) recommends a combination of several complementary diagnostic tests for assessing daytime sleepiness. Since the recommended tests only cover certain aspects of daytime sleepiness, it has not been possible to establish a single test method that could be used as a standard for validating other methods (Weeß 2018).

In choosing the tests, one focus was on ensuring that they covered various components of attention (tonic central nervous system activation, phasic central nervous system activation, vigilance / sustained attention) and on complementing computer-based psychometry with an independent test (pupillography).

The aim of this study was to identify a test method that is easy to administer even for inexperienced users and that detects sleepiness with high levels of sensitivity and specificity.

2. METHODS

The vigilance of night-duty nursing staff of the Bundeswehr Hospital in Hamburg was tested immediately before and after a night shift. Each test lasted 90 minutes. The night shift began at 9 pm, and the evening tests were carried out between 7.30 pm and 9 pm. The night shift ended at 6.30 am, with the test thus lasting until 8 am. Based on the nature of their work, it was postulated that they would not get any sleep during the night of the test. Subjects were asked to confirm this before testing in the morning.

We used the following objective and subjective tests in this study:

- two objective tests to examine vigilance / sustained attention:
    a) S1 vigilance test with circular path according to Quatember and Maly (VIGIL®)
    b) measurement of visual vigilance with WAFV test, S2 test battery from the Schuhfried SLEEP® test battery
- two objective tests to determine daytime sleepiness:
    a) pupillographic sleepiness test
    b) measurement of tonic and phasic central nervous system activation with the Schuhfried SLEEP® subtest
- the Stanford Sleepiness Scale (SSS), a scale for subjective assessment of the current level of sleepiness.

The test procedure was standardised, with the test sequence and intervals between the individual tests predefined.

Before the tests started, each subject had to fill out the SSS. The first test was the pupillography test. After an interval of 5 minutes, the vigilance test (VIGIL®) was then performed. And lastly, after another 5-minute interval, the WAFV test (SLEEP® test battery) was carried out to assess phasic and tonic central nervous system activation and to measure visual vigilance.

Five days after the test, the subjects were contacted again and asked up to which point on the SSS they would consider themselves to be fit to drive. The purpose of asking this question at a later point was to obtain an objective self-assessment. It was necessary to avoid situations where subjects might consider themselves sleepy after the morning measurement but did not wish to have this recorded because of their intention to drive afterwards.

Nurses of the Federal Armed Forces Hospital Hamburg, who were between 20 and 40 years old, came as probands in question. In a preliminary interview they were asked about possible health restrictions. Only healthy subjects were accepted. Gender was not specified. The study design was approved by the Ethics Commission of the Medical Association (Ethikkommission der Ärztekammer) in Hamburg (PV 4909) and it was part of a military medical research project (SoFo19K2-S-32 1515).

To test statistical significance, non-parametric tests were used because the data collected was not expected to be distributed normally. All tests were evaluated using two-sided significance tests. A test shows impaired vigilance if at least one of the measurements collected falls within the pathological range. A subject is objectively sleepy if at least two different tests (other than SSS) show a reduced level of vigilance. The definition was based on the German Guidelines on Assessment of Fitness to Drive

Gräcmann & Albrecht 2017). These guidelines define sleepiness as objectifiable if a method used to test central nervous system activation or vigilance reveals at least one abnormal result or if two attention functions show abnormal results. All evaluations were carried out with IBM SPSS Statistics 19.

In total, 16 male and 14 female subjects were tested. There were not enough subjects for a statistically significant gender-specific analysis and results were not differentiated based on specific test nights (e.g. the first night of a night-duty period).

2. RESULTS

2.1 Overview of impaired vigilance before and after a night shift

The greatest change over the course of the night shift towards greater sleepiness was evident on the SSS, in the number of correct reactions and the reaction time in the VIGIL test, and in the number of missed reactions and the reaction time in the WAFV test. The number of missed stimuli with tonic activation, which was reduced after the night shift, went the other way (overview of all tests, Table 1).

Table 1: Results of the individual sleepiness tests before and after night shift. Mean values (MV), standard deviations (SD) and overview of the central tendencies in the Wilcoxon Test. SSS = Stanford Sleepiness Scale, PUI = pupillary unrest index, VIGIL = vigilance test, WAFV = visual vigilance test

		Before night shift		After night shift		Difference		Wilcoxon Test	
Test	Parameter	MV	SD	MV	SD	MV	SD	Z	p
SSS		1.77	0.69	3.43	1.04	-1.67	0.92	4.731	**< 0.001**
PUI		5.94	3.07	6.79	4.11	-0.85	3.39	1.213	0.225
VIGIL	Correct reactions	53.13	28.42	23.27	25.38	29.87	32.42	3.841	**< 0.001**
	False reactions	44.93	23.41	34.27	29.52	10.67	35.18	1.772	0.076
	Reaction time	63.40	30.43	43.30	31.22	20.10	28.64	3.412	**0.001**
WAFV	Missed stimuli	59.87	29.05	35.13	30.88	24.73	39.60	2.982	**0.003**
	False reactions	34.77	24.25	22.13	26.68	12.63	33.09	2.135	**0.033**
	Reaction time	69.87	26.57	57.77	29.52	12.10	26.43	2.528	**0.011**
Tonic activation	Reaction time	68.17	21.21	63.10	21.67	5.07	18.27	1.264	0.206
	Motor time	69.13	20.89	68.47	23.80	0.67	16.22	0.036	0.971
	Missed stimuli	52.20	14.65	55.17	10.04	-2.97	12.31	1.089	0.276
Phasic activation	Reaction time	70.03	21.51	64.80	25.11	5.23	24.33	0.887	0.375
	Motor time	72.37	18.94	70.20	21.74	2.17	11.45	0.958	0.338
	Missed stimuli	53.00	0.00	48.00	15.26	5.00	15.26	1.633	0.102
	Reaction time difference	52.43	24.15	52.23	28.15	0.20	38.14	0.022	0.983
	Motor time difference	55.87	25.13	53.87	26.05	2.00	25.50	0.680	0.496

2.2 Share of subjects with impaired vigilance

Vigilance was objectively impaired in 60 % of subjects after the night shift. This is best reflected in the VIGIL and WAFV tests. In contrast, tonic activation after the night shift shows fewer sleepy subjects.

The vigilance of 20 % of the subjects was already impaired before their night shift began.

Table 2: Objectively sleepy subjects (for definition, see above) before and after night shift, and sensitivity in the individual tests. PUI = pupillary unrest index, VIGIL = vigilance test, WAFV = visual vigilance test, tonic / phasic = tonic / phasic central nervous system activation.

	n	Objectively sleepy	PUI	VIGIL	WAFV	Tonic	Phasic
Before night shift	30	6 (20.0 %)	3 (10.0 %)	8 (26.7 %)	9 (30.0 %)	3 (10.0 %)	3 (10.0 %)
After night shift	30	18 (60.0 %)	6 (30.0 %)	19 (63.3 %)	20 (66.7 %)	2 (6.7 %)	8 (26.7 %)

2.1 Sensitivity and specificity of the individual tests

The following evaluations do not distinguish between whether a subject was examined before or after a night shift. The data is seen as a collective of 60 data sets with varying degrees of impaired vigilance. In total, there were six objectively sleepy subjects before night shift and 18 sleepy subjects after night shift (cf. Table 2).

Sensitivity refers to the share of all objectively sleepy subjects (here $n = 24$) who were also identified as such in the respective test.

Specificity is the share of all subjects who were objectively not sleepy (here $n = 36$) and who are classified in the respective test as not sleepy.

Table 3: Sensitivity and specificity of the individual tests in terms of assessing sleepiness. PUI = pupillary unrest index, VIGIL = vigilance test, WAFV = visual vigilance test, tonic / phasic = tonic / phasic central nervous system activation.

	PUI	VIGIL	WAFV	Tonic	Phasic
Sensitivity	37.5 %	95.8 %	100.0%	12.5 %	41.7 %
Specificity	100.0 %	88.9 %	86.1 %	94.4 %	97.2 %

The VIGIL and WAFV tests show good sensitivity and acceptable specificity. PUI and tonic and phasic activation show poor sensitivity and reasonable specificity. VIGIL and WAFV are therefore recommended methods for identifying impaired vigilance.

2.2 How reliable is self-assessment?

Table 4 compares the self-assessment of sleepy subjects with that of subjects who are not sleepy. There is no significance as regards subjective fatigue in this context

Table 4: Comparison of the self-assessments of subjects who are objectively sleepy and those who are objectively not sleepy. This table shows the mean values (MV), standard deviation (SD), sample size (n) and the results of the Mann-Whitney *U* test (Z value = test statistic, p value = probability measure, SSS = Stanford Sleepiness Scale.

	SSS			Mann-Whitney *U* Test	
	MV	SD	n	Z	p
Objectively not sleepy	2.56	1.229	36	0.524	0.600
Objectively sleepy	2.67	1.204	24		

A comparison with the self-assessment values from Table 1 before/after a night shift shows that the subjects generally assess themselves as sleepier after night shifts but that this assessment does not correspond to the actual degree of sleepiness.

This SSS points score specified by the subjects in the follow-up survey was compared with their self-assessments of their sleepiness on the SSS after the night shift. It follows that subjects would consider themselves unfit to drive if their indicated level of sleepiness after the night shift was higher than their subjective limit in terms of fitness to drive. Otherwise, subjects considered themselves fit to drive after the night shift. Based on this assumption, two thirds of the subjects with impaired vigilance still consider themselves to be fit to drive, while only half of the subjects who are not sleepy do so (Table 5).

Table 5: A comparison of the percentage and absolute numbers of subjects who were objectively not sleepy or sleepy after a night shift with those of subjects who were subjectively fit to drive or not fit to drive.

After night shift	Objectively not sleepy	Objectively sleepy
Subjectivelyfit to drive	6 of 12 (50 %)	12 of 18 (67 %)
Subjectively notfit to drive	6 of 12 (50 %)	6 of 18 (33 %)

3. CONCLUSIONS

In the study, common neuropsychological measuring methods for the presentation of sleepiness, proposed by the German Society for Sleep Research and Sleep Medicine, and a scale for the subjective assessment of the current drowsiness were compared. One focus was the juxtaposition of different attention components (tonic central nervous activation, phasic central nervous activation, vigilance / sustained attention). It was to be clarified which measurement method proves a vigilance-related attention deficit with the highest sensitivity and specificity.

As psychometric testing revealed, 60 % of the subjects (18 out of 30) showed no longer a high enough level of vigilance to drive a car after working at night (in this case the night shift in a hospital). Two thirds (12 out of 18) of those with abnormal psychometric results still considered themselves fit to drive, however.

Impaired vigilance can be identified at an early stage by screening the attention components vigilance / sustained attention (Quatember and Maly Vigilance Test S1 with circular path and the WAFV test from the Schuhfried SLEEP® test battery). In compare to this self-assessment scales (here: Stanford Sleepiness Scale) are unsuitable for detecting loss of vigilance. Subjects cannot accurately assess their own sleepiness.

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The test methods that were used to determine tonic central nervous system activation (here: pupillography and Schuhfried® SLEEP test battery subtest) exhibit low specificity but very high specificity for moderate sleep deprivation. These vigilance tests are characterized by a short test duration (pupillography 11 minutes, Schuhfried subtest battery 4 minutes). It is conceivable that the vigilance impairments caused by moderate sleep deprivation can be compensated through willpower during these short measurements. In addition, the subjects began the test series with the pupillography and thus still had the largest reserves at this time. If deficits were found in the testing of tonic-central nervous activation, their specificity was markedly high (pupillography 100%, WAFV 94.4%)

The result of a study by Grellner et al. (2005) presents itself in accordance with this hypothesis. This showed that after the night shift the PUI of night-care nurses had only a relatively moderate (but significant) increase, which, when considered as an absolute value, was increased only in the grey area. Only after additional demanding one-hour continuous load (Vienna test system), there was a further significant increase with a pathological absolute value.

Another cause for the low sensitivity of pupillography with only a slight increase in PUI may be due to the rather moderate sleep deprivation. Already Manousakis (Manousakis et al., 2017) describes a relevant increase in PUI only after a sleep deprivation of 20 hours.

The phasic-central nervous activation was expected to have a low sensitivity: On the one hand, nursing staff is characterized by being able to react quickly and adequately to critical stimuli (eg in emergency situations) and to be able to intuitively implement this even with limited vigilance. On the other hand, this 4-minute drowsiness test is so short that vigilance impairments can be most readily compensated through willpower in accordance with the testing of tonic-central nervous activation.

There are several preliminary studies comparing drowsiness diagnostics. The Multiple Sleep Latency Test, or the Maintenance of Wakefulness Test, are frequently used as references. A comparison of current psychometric drowsiness diagnostics is not yet demonstrable. Therefore, the results of the test psychometric subgroups phasic and central nervous activation or visual vigilance cannot be set in the context of previous studies.

As initially hypothesised, subjective self-assessment of sleepiness correlates very unclearly with objective test results. People with impaired vigilance find it more difficult to assess their own performance (Philip et al., 2001; Weeß et al., 2001). Already Danker-Hopfe et al. (2001) found that subjective self-assessment on the SSS does not correlate with objective measurements of tonic central nervous system activation (pupillography test and Multiple Sleep Latency Test). Vigilance deficits are detected early by a screening of the attention components vigilance / sustained attention (Quatember and Maly Vigilance Test S1 with circular path and the WAFV test from the Schuhfried SLEEP® test battery). Test methods for the demonstration of the attention component of tonic central nervous activation (here: pupillography and subtest test battery SLEEP from Schuhfried®) and the phasic central nervous activation (here: Schuhfried® SLEEP test battery subtest) show a low specificity in moderate sleep deprivation.

The temporal adaptation of the vigilance measurements to the shift model of the night shift motivated the subjects to participate actively in the tests. This was demonstrated, among other things, by the fact that the participants appeared punctually on the dates of the measurements and that they regularly had their results explained. Innovative is the bundling and thus comparability of several renowned drowsiness tests.

Certainly, the number of subjects is rather small. Nevertheless, the earnings trend seems very clear.

As a follow-up a further special military medical research project has been approved: Here the Quatember-

Maly vigilance test, which was found to be the gold standard, will be compared with a three-minute test for identifying sleepiness. The latter test is performed on a portable handheld computer and is therefore also suitable for mobile measurements in a deployed setting. It was developed by the Department of Aviation and Space Psychology of the Cologne-based German Aerospace Center.

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