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# Fatigue at sea

## A field study in Swedish shipping

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The purpose of this study was to collect data about the fatigue level of bridge watch keepers to use for revising earlier sleep models, and devise innovative solutions for the shipping industry.

Data collection included interviews with shipping companies and a field study onboard 13 cargo vessels. 32 participants took part in representing two watch systems; 2-watch and 3-watch. Subjective sleepiness and stress estimations were performed once every hour. EOG was used to record eye movement behaviour. Reaction time test was made to examine performance.

3-watch participants are more satisfied with their working hours and working situation. Tendencies indicate that 2-watch participants are a bit more tired, whereas the stress is the same. All are less sleepy and less stressed at home. Time on shift had effect on sleepiness. The highest KSS scores were recorded in the late night and early morning. After night shift the reaction times have higher variance and more long reaction times are present. The mean value after night shift was significantly higher than after day shift.

All thirteen shipping companies agreed that officers on the bridge always have tasks sensitive to fatigue but no company experienced fatigue as a problem during normal conditions. All were positive to monitoring devices, mentioning safety matters.

**Keywords**:
Fatigue, shipping, shift work, 2-watch ships

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Trötthet ombord – En fältstudie inom Svensk sjöfart

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Syftet med denna studie var att samla kvantitativa data om trötthetsnivån bland styrmän ombord att användas för revidering av tidigare sömnmodeller och för nya innovativa lösningar för sjöfartsindustrin.

Datainsamlingen bestod av intervjuer med rederier och en fältstudie på 13 lastbåtar. Deltagande var 32 personer som representerade två vaktsystem; tvåvakt och trevakt. Subjektiva skattningar av sömnighet och stress gjordes en gång i timman. EOG användes för att mäta ögonrörelser. Reaktionstidstest användes för att mäta prestation.

Deltagare i trevaktsystemet är mer tillfreds med arbetstider och arbetssituation. Tendenser indikerar att deltagare i tvåvaktssystemet är lite tröttare medan stressnivån är densamma. Deltagarna i båda vaktsystemen är mindre sömniga och mindre stressade hemma. Tiden på skiftet påverkade sömnigheten. De högsta KSS-värdena gavs sent på natten och tidigt på morgonen. Reaktionstidstestet gav större varians efter nattskift och även fler långa reaktionstider återfanns då. Medelvärdet var signifikant högre än efter dagskift.

Alla tretton rederier var eniga om att styrmän på bryggan alltid har uppgifter som är känsliga för sömnighet, men ingen såg det som ett problem under normala förhållanden. Samtliga är positiva till övervakningssystem och uppger sjöfartssäkerhet som främsta orsak.

**Nyckelord:**

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*Margareta Lützhöft*

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## Quality review

Review seminar was carried out on 15 June 2007 where Håkan Alm, Luleå University of Technology, reviewed and commented on the report. The authors have made alterations to the final manuscript of the report 1 July 2007. The research director of the project manager Lena Nilsson examined and approved the report for publication on 12 September 2007.

## Kvalitetsgranskning

Granskningsseminarium genomfört 15 juni 2007 där Håkan Alm, Luleå Tekniska Universitet var lektör. Författarna har genomfört justeringar av slutligt rapportmanus 1 juli 2007. Projektledarens närmaste chef Lena Nilsson har därefter granskat och godkänt publikationen för publicering 12 september 2007.

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# Abbreviations

| | |
|---|---|
| AMSA | Australian Maritime Safety Authority |
| DP | Dynamic Positioning |
| EEG | Electroencephalography |
| EMG | Electromyography |
| EOG | Electrooculography |
| IMO | International Maritime Organization |
| KI | Karolinska Institute |
| KSS | Karolinska Sleepiness Scale |
| MAIB | Marine Accident Investigation Branch |
| PERCLOS | Percent Eye Closure |
| SD | Standard Deviation |
| SMA | Swedish Maritime Administration |
| SWP | Sleep/Wake Predictor |

**Fatigue at sea – A field study in Swedish shipping**

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## Summary

There is no standardized methodology for the recording of sleepiness or fatigue, in individuals driving a vehicle. However, there are recording techniques that have been commonly used e.g. EEG (electrical brain waves) and, in most cases, EOG (eye movements). Another technique refers to subjective ratings which is the simplest way of measuring driver sleepiness. The Karolinska Sleepiness Scale (KSS) is a nine-graded scale (1 very alert and 9 very sleepy) where signs of sleepiness increase considerably at the level of 8 and 9. Working on a ship's bridge means in most instances working irregular work hours, including night work. There are negative effects of irregular work hours, which are mainly a consequence of two factors – the biological 24h-hour rhythm and sleep loss.

The purpose of this study was to collect quantitative data about the fatigue level of bridge watch keepers on board ships, using several methods and techniques. This data corpus will be used to revise earlier sleep models, and to devise innovative solutions for the shipping industry. The ultimate purpose was to construct solutions that lead to safe manning of ships while acknowledging economical constraints.

The data collection consisted of interviews with shipping companies and a field study performed during visits (3–5 days) onboard 13 cargo vessels of different types, such as bulk carriers, car carriers and tankers. Four types of instruments were used for data collection during the onboard visits; questionnaires and diaries, EOG, activity meters and reaction time tests. Originally there were 32 participants in the study, but due to loss of data only 30 were included in the analyses. Two watch systems were included; the two-watch 6 on/6 off and the three-watch 4 on/8 off systems.

The participants answered a questionnaire concerning general health. Sleep quality was measured by filling in sleep diaries after each period of sleep, including sleep on daytime off-duty periods. Subjective sleepiness estimations were performed once every hour using KSS. Participants were at the same time asked to rate their level of experienced stress, on a similar 9-point scale. EOG was measured with electrodes placed at five places around the eyes. The technique was used to record eye movement behaviour in the horizontal and vertical directions. A reaction time test was given to the participants to examine differences in performance after daytime and night time watches.

The main result is that, although no statistical difference was found, all tendencies point in the same direction: there are higher levels and effects of fatigue on two-watch ships.

Participants in the three-watch system are more satisfied with their working hours and working situation than participants in the two-watch system. Both watches are similarly satisfied with their working tasks. Tendencies suggest that participants in the two-watch system more often get less than 6 hours sleep a day, more often nod off and more often

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fight against sleep than participants in the three-watch system. Most participants think they need at least eight hours sleep a day. Tendencies suggest that the participants in the two-watch system are a bit more tired, especially in the early morning and in the afternoon, whereas the stress level is about the same. The mean values also indicate that both watches are less sleepy and less stressed at home than on board. The results indicate that participants are more tired when going to sleep at home than on board and more rested when getting up at home than on board. Tendencies show that both sleep quality and sleep length is better at home than on board but no significant difference was found.

The mean KSS scores increased somewhat during shift hours. A tendency towards higher KSS scores in the two-watch system is evident, especially at the end of shift. The highest percentage of KSS scores over 5 was scored when the participants worked longer than the planned shift. The last working hour for both shift systems only KSS scores over 5 were scored. This shows that time on shift affects sleepiness. There is a tendency that the two-watch system leads to higher KSS mean values. two-watch participants were also more fatigued at the end of shift than three-watch participants. The highest KSS scores were recorded in the late night and early morning hours. Night time hours induced higher tiredness than day time work. The two-watch led to a larger amount of high KSS scores. In 2.7% of all scores participants had difficulties in staying awake (8 or 9) and in 82% of these the participant worked in two-watch.

We have reason to believe that participants have rated their own sleepiness a bit carefully. Some have expressed worries about being in a study and feeling observed. We had expected greater differences between KSS values sleep quality and sleep length at home and on board. The reason for the small differences could possibly be explained by the suspicion of low ratings in general but also by the fact that ratings were given at home the first three days after a long on board period and this is not entirely representative for the total home period.

Most ratings over 7 come from two-watch participants and most from the night shifts. KSS scores at watch-change are high and can possibly be explained by the fact that the mate starting just woke up and the mate getting off is on his way to bed. With more shifts worked the participants get more tired. Some filled in the diary every hour. Others might fill in afterwards, for a few hours, or for a whole watch. These different strategies may have influenced the scoring.

After the night shift the reaction time scorings have higher variance and more scorings with long reaction times are present. The mean value after night shift was significantly higher than after day shift. Only a slight tendency to higher values for the two-watch was found. The high variance after night shifts is similar to that seen when testing for alcohol levels over 4 parts per thousand. Generally it can be said that participants scored higher reaction times after a night shift than after a day time shift. This has been shown before in many domains, and here, again, it is shown that humans are not made for night work.

All thirteen companies in the interviews agreed that officers on the bridge always had tasks that were sensitive to fatigue but no company experienced fatigue as a problem during normal conditions. All are aware of the fatigue problem, but some of them do not believe it is a large problem. Many ships have a warning system where the crew has to reset the system every 30 minutes or so. Two of the companies answered that this system is very disturbing for the crew on duty, a better system would be one which was only initiated when the person is tired. All the companies are positive to monitoring devices, but the equipment must be comfortable to wear and the crew has to know the reason why they should wear it. Seven of the companies are willing to buy such equipment. Maritime safety matters were the most common cause for these answers and a good functionality was another.

**Trötthet ombord – En fältstudie inom svensk sjöfart**

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## Sammanfattning

Det finns ingen standardmetod för att mäta trötthet eller sömnighet på förare, men det finns några mätmetoder som brukar användas. En av dessa är EEG (elektriska hjärnvågor) som ofta används tillsammans med EOG (ögonrörelser). En annan metod bygger på subjektiva skattningar vilket är det enklaste sättet att mäta förartrötthet. Karolinska sleepiness scale (KSS) är en niogradig skala (1=extremt pigg och 9=extremt trött) där tecken på trötthet ökar avsevärt vid nivåerna 8 och 9. Att arbeta på bryggan på en båt innebär oftast oregelbundna arbetstider och nattarbete. Detta har negativ påverkan på kroppen främst beroende på kroppens biologiska 24-timmars rytm och sömnbrist.

Syftet med denna studie var att samla kvantitativa data om trötthetsnivån bland styrmän ombord genom att använda olika metoder och tekniker. Denna datamängd kommer att användas för att revidera tidigare sömnmodeller och för att tänka ut innovativa lösningar för sjöfartsindustrin. Det övergripande syftet var att konstruera lösningar som leder till säker manövrering av fartygen och samtidigt ta hänsyn till ekonomiska restriktioner.

Datainsamlingen bestod av intervjuer med rederier och en fältstudie som genomfördes under besök på 13 lastfartyg av olika typ, som bulk-, bil- och tankfartyg. Fyra olika metoder användes för insamling av data ombord; enkäter och dagböcker, EOG, aktivitetsmätare och reaktionstidstest. Ursprungligen deltog 32 personer i studien, men på grund av databortfall inkluderades bara 30 i analysen. Två vaktsystem var representerade; tvåvakt 6 h på/6 h av och trevakt 4 h på/8 h av.

En generell hälsoenkät delades ut till deltagarna. Sömnkvalitet mättes med hjälp av sömndagböcker som fylldes i efter varje sömnperiod, även efter sömn på frivakten på dagtid. Deltagarna gjorde även subjektiva skattningar av sömnighet en gång i timman med hjälp av KSS-skalan och ombads samtidigt skatta sin stressnivå på en liknande niogradig skala. EOG mättes med elektroder placerade på fem punkter runt ögonen. Tekniken användes för att mäta horisontella och vertikala ögonrörelser. Ett reaktionstidstest genomfördes för att undersöka skillnader i prestation efter dagskift och nattskift.

Ett sammanfattande resultat är att, trots att det inte statistiskt säkerställts, alla tendenser pekar i samma riktning: nivåerna och effekterna av trötthet på tvåvaktsfartyg är högre.

Deltagare i trevaktsystemet är mer tillfreds med sina arbetstider och sin arbetssituation än deltagare i tvåvaktssystemet. Båda vaktsystemen är lika nöjda med sina arbetstider. Tendenser visar att deltagare i tvåvaktsystemet oftare får mindre än 6 timmars sömn per dag, oftare nickar till och oftare kämpar mot sömnen än deltagarna i trevaktsystemet. De flesta tycker att de behöver minst 8 timmars sömn per dag. Tendenser visar också att deltagare i tvåvaktssystemet är lite tröttare, speciellt tidigt på morgonen och på eftermiddagen, medan stressnivån är ungefär densamma för båda vaktsystemen. Medelvärdena indikerar även att deltagarna i båda vaktsystemen är mindre sömniga och mindre stressade hemma än ombord. De är också sömnigare när de går och lägger sig

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och mer utvilade när de går upp hemma än ombord. Tendenser visar att både sömnkvalitet och sömnlängd är bättre hemma än ombord, men inga signifikanta skillnader fanns.

Medelvärdena av KSS ökade något under nattskiften. En tendens mot högre KSS-värden i tvåvaktsystemet är tydlig, speciellt i slutet på skiftet. Högst procent KSS-skattningar över 5 gavs när deltagarna arbetade längre än det planerade skiftet. Den sista arbetstimman för båda skiften hade bara KSS-skattningar över 5. Detta visar att tiden på skiftet påverkar sömnigheten. Tvåvaktsystem tenderar att ge högre KSS-medelvärden. Styrmännen från tvåvakt var också sömnigare i slutet på skiftet än de från trevakt. De högsta KSS-värdena gavs sent på natten och tidigt på morgonen. Nattarbete inducerade högre sömnighet än dagarbete. Tvåvaktssystemet fick större antal höga KSS-skattningar. Svårigheter att hålla sig vaken angavs i 2,5 % av skattningarna och i 82 % av dessa arbetade deltagaren i tvåvakt.

Vi har anledning att tro att deltagare skattat sin egen sömnighet något försiktigt. Några har uttryckt oro över att vara med i en studie samt över att vara observerade. Vi hade förväntat oss större skillnader mellan KSS-värden, sömnkvalitet och sömnlängd hemma och ombord. Anledningen till de små skillnaderna skulle kunna förklaras med misstanken om låga skattningar generellt, men också av det faktum att skattningarna hemma gavs de tre första dagarna hemma efter en lång ombordvistelse och därför kanske inte är så representativa för hemmaperioden.

De flesta skattningar över 7 kommer från tvåvakt och oftast från nattskift. KSS-skattningar vid vaktskifte är höga och kan troligtvis förklaras av att den styrman som börjar sitt skift just har vaknat och den som slutar sitt skift är på väg att lägga sig. Med fler arbetade skift blir deltagarna mer trötta. Några fyllde i sömndagboken varje timma, andra fyllde i efter några timmar eller för en hel vakt. Dessa olika strategier kan ha påverkat skattningarna.

Reaktionstidstestet gav större varians efter nattskift och även fler långa reaktionstider återfanns då. Medelvärdet av reaktionstiderna var signifikant högre efter nattskift än efter dagskift. Bara en tendens till högre värden för tvåvaktssystemet fanns. Den högre variansen efter nattskiften är en typ av varians man även ser vid alkoholtester, vid utslag över 0,4 promille. Generellt kan sägas att deltagarna hade längre reaktionstider efter nattskift. Det har visats förut i många sammanhang och här visas igen att människan inte är gjord för nattarbete.

Alla tretton rederier som deltog i intervjuerna var eniga om att styrmän på bryggan alltid har uppgifter som är känsliga för sömnighet, men ingen såg det som ett problem under normala förhållanden. Alla är medvetna om att problemet med sömnighet finns, men en del av dem tror inte att det är ett stort problem. Många fartyg har varningssystem där besättningen måste trycka på en knapp var 30:e min. Två av rederierna tyckte att det systemet är väldigt störande för arbetande besättning och skulle hellre se ett som initierades först när personen blir trött. Samtliga rederier är positiva till övervakningssystem, men utrustningen måste vara bekväm att bära och besättningen måste veta anledningen till att de ska ha den. Sju av rederierna är villiga att köpa sådan utrustning. Sjösäkerhet angavs som den vanligaste orsaken till detta men även bra funktionalitet.

# 1 Introduction

This document presents results of parts of the Fatigue at sea project performed during 2005–2007. The purpose of the project as a whole was to collect subjective and objective data useable for a thorough investigation of sleepiness, stress and performance levels of watch keeping officers on Swedish ships. The project consists of several parts:

1. A literature review.
2. Work and rest hours logging. We wished to collect data on seafarers' real working hours in parallel with, but separate from, the field study. There are suspicions that work and rest regulations are not followed.
3. An onboard study, measuring physiological data to compare the two-watch system to the three-watch system.
4. A simulator study in which 10 seafarers "sailed" the two-watch system for 6 days
5. An interview series with shipping companies
6. A study of marine pilots, boatmen and VTS, bridge and lock operators at the Swedish Maritime Administration working in a shift system
7. Evaluation and verification, including recommendations.

In this report, the onboard (field) study and the interviews will be presented. All parts of the study are discussed briefly below.

1. Literature review. As the subject is of a current large interest, and a number of good reviews exist (and are in progress), we focused on a limited review and looked also at existing regulations. It is available on www.vti.se/fatigueatsea.
2. Work/rest logging. Students at Kalmar Maritime Academy performed a final year project in 2006 (in Swedish) called "Trötthetsfaktorer till sjöss". The Nautical Institute (endorsing the present project) also performed a study, available at http://www.nautinst.org/fatigue/index.htm.
3. An on-board field study, preceded by pilot studies. The main results are presented in this report.
4. A ship simulator study was performed, in order to gather data on 6x6 watches in a controlled environment. A separate report is in preparation.
5. Shipping company interviews. Presented in this report.
6. A study of work and rest hours on marine pilots, boatmen and VTS, bridge and lock operators in Sweden. The results are published as a separate report in Swedish, available at www.vti.se/fatigueatsea.
7. Evaluation, verification, recommendations. Recommendations are being evaluated and will be published in a separate report. In that same report the Karolinska Institute Sleep/Wake Predictor (SWP) will be discussed. It has for instance been used to evaluate some of the recommendations. Data from this project will be incorporated into the SWP.

# 2 Background

This background reviews fatigue, sleepiness and drowsiness on a general level and for drivers; it describes current measures of fatigue, their benefits and drawbacks. We end by specifically discussing fatigue on board ships and the related risks both for individuals and for maritime safety.

## 2.1 Fatigue and sleepiness

In the literature, terms such as fatigue, sleepiness and drowsiness are used interchangeably. In USA, the term fatigue is often used in the driver context, whereas European researchers often prefer the terms sleepiness and drowsiness. Nevertheless, the concepts sleepiness, drowsiness and fatigue all seem to refer to the driver's level of wakefulness and whether the driver has shown signs of falling asleep at the wheel.

Sleepiness is operationally defined as a physiological drive to sleep. This is the latent, fundamental type of sleepiness that in some cases can be masked by surrounding factors, such as social interaction, stress, physical activity, coffee etc., and result in manifest sleepiness. Hence, the manifest (experienced) sleepiness is often lower than the latent (actual) sleepiness. However, during certain driving conditions, e.g. monotonous driving on a boring road, contextual factors increase the manifest level of sleepiness beyond the underlying, latent level of sleepiness and drivers feel more sleepy because of being bored. In reality, the short-term variation in sleepiness may often be determined by environmental factors, which can both increase and decrease the sleepiness level. Thus, sleepiness (particularly subjective ratings) is to a large extent context dependent (Eriksen, Åkerstedt, & Kecklund, 2005). As a consequence, one may perceive oneself as being fairly alert because of masking. But when masking is removed, a dramatic and surprising increase in sleepiness will be experienced. Taking context related factors into account, driver sleepiness can be seen as the lack of ability to maintain a wakeful state of attention without the aid of the situational factors.

Definitions of fatigue usually include the inability or disinclination to continue an activity, generally because the activity has, in some way, been going on for "too long". This may be due to an earlier activity, exhausting resources that normally recover. One can conceive of different kinds of fatigue, such as local physical fatigue (e.g. in a skeletal muscle), general physical fatigue, mental fatigue (e.g. following sustained attention due to a long-lasting high mental workload) or "central nervous system" fatigue (sleepiness). Thus, fatigue is often considered to be a generic term of which sleepiness is one of the major sub-components. In a driving context, sleepiness and mental fatigue are the most relevant fatigue components.

### 2.1.1 Driver fatigue

Falling asleep when driving is a prevalent phenomenon that has severe implications for traffic safety. In a field study on truck drivers, 7% of the driving time included sleepy driving measured with video recordings of the drivers' face (Mitler, Miller, Lipsitz, Walsch, & Wylie, 1997). Mitler and co-workers also reported clear individual differences in sleepy driving. A minor group of 8 drivers accounted for more than 50% of the sleepy driving epochs. Moreover, 44% of the drivers showed no sleepiness signs at all, despite driving at night when driver sleepiness usually peaks.

Sleepy driving accidents have been estimated to be involved in at least 15–20% of the accidents (Horne & Reyner, 1996). Norwegian data of in-depth accident investigations showed that sleepiness was involved in 29% of the crashes, which was more than alcohol related accidents (11%) (Moe, 1999). Recently, the 100-car study, in which approximately 100 cars were monitored during a year, showed that sleepy driving resulted in 4 to 6 times higher accident/near-accident risk compared to baseline driving when the driver was in an alert state with high level of attention (Klauser, Dingus, Neale, Sudweeks, & Ramsey, 2006). The prevalence of sleep related accidents (including near accidents) was estimated to 22–24%.

### 2.1.2 Measurements of fatigue

There is no standardized methodology for the recording of sleepiness, and for the quantification of involuntary sleep, in individuals driving a vehicle. However, there are five recording techniques that have been commonly used (Ji, Zhu, & Lan, 2004). One technique is based on the recording of EEG (electrical brain waves) and, in most cases, EOG (eye movements), (Lal & Craig, 2002). EMG (muscle tension) may also be used, although it is often excluded due to interference with the driving task.

Another common technique that has received a lot of attention with respect to driver sleepiness, is camera based eye movement recordings (Barr, Popkin, & Howarth, 2005). This technique is more feasible in many driving studies since it is contact-less and suitable for on-line analysis (Ji et al., 2004). The eyes are recorded with cameras in order to acquire video images of the driver. The visual cues of sleepiness are mainly eye blinking, including blink frequency, blink duration, long closure time, pupil diameter, gaze and sometimes also saccadic eye movements.

A third technological category refers to behavioural signs of sleepiness, such as body movements, gestures, facial tone and head movements (Wierwille & Ellsworth, 1994). The head is measured with cameras and the recordings are subjected to video image analysis or to observer ratings. The indicators of sleepiness are a sluggish and expressionless facial tone, yawning, nodding (head tilts) and a sagging body posture.

A fourth category refers to driving parameters associated with performance impairment during sleepy driving (Brookhuis et al., 1998). It is well known that sleepy driving is associated with impaired driving performance. Since impaired driving should be closely linked to accidents or more serious driving errors it has been tempting to use performance measures as indices of driver sleepiness (Brookhuis et al., 1998). However, performance measures should be regarded as an indirect measure of driver sleepiness since it reflects the consequences of sleepiness.

A fifth category refers to subjective ratings of sleepiness. Ratings are the simplest way of measuring driver sleepiness. However, it is also of great interest to know more of how drivers' perceive sleepiness and whether their perception correlates with objective indices of sleepiness.

**Eye movements**

Many of the variables proposed in the literature as being sensitive to sleepiness and fatigue are related to the blink complex (opening and closing of the eyelid). Thus, it has consistently been shown that blink rate (blink frequency) increases as a function of time on task and this pattern has been interpreted as a sign of increased sleepiness and mental fatigue (Stern, Boyer, & Schroeder, 1994). It has also been suggested that blink rate may reflect eye or visual fatigue (Sirevaag & Stern, 2000). However, blink rate is also affected by other factors than sleepiness. For example, blink rate is partly task dependent (Luckiesh, 1947) and influenced by visual demands (Sirevaag & Stern, 2000). Hence, blink rate should probably be regarded as a rather non-specific indicator of sleepiness.

A more specific parameter of the blink complex is blink duration and long closure blinks. There are many studies showing that blink duration as well as the proportion of long closure blinks increases when subjects are sleepy (Caffier, Erdmann, & Ullsperger, 2003; Sirevaag & Stern, 2000). The increase has also been demonstrated in field and simulator studies of driving or flying (Häkkinen, Summala, Parinen, Tiihonen, & Silvo, 1999; Ingre, Åkerstedt, Peters, Anund, & Kecklund, 2006; Morris & Miller, 1996). There are also other variables such as blink amplitude, lid closure speed and lid re-opening speed that have been considered sensitive to variations in sleepiness. So far, these variables have been studied less than blink rate and blink duration. The results suggest that sleepiness is associated with decreased blink amplitude, lid closing speed and lid re-opening speed (Morris & Miller, 1996; Caffier et al., 2003; Ji et al., 2004). A problem with the blink measures is the large inter-individual differences. (Galley, Schleicher, & Galley, 2004) showed that the changes in blink parameters associated with increasing sleepiness differed a lot between individuals. For example, since the intra-individual correlations with subjective ratings of sleepiness ranged from -0.50 to 0.98 it seems unlikely that blink duration should be the prime indicator of sleepiness for all individuals. Ingre et al. (2006) have also observed large individual differences in blink duration in the response to sleepy driving. Thus, one should not rely on any of the blink metrics alone to characterize the level of sleepiness.

Morris and Miller (1996) have observed strong correlations with specific eye and eyelid movement measures and performance decrements in a flight simulator. In a multiple regression analysis, blink amplitude (decreased), blink rate (increased) and long closure rate (increased) predicted 61% of the variance of certain performance errors. The best predictor was blink amplitude and the authors interpreted the decreased amplitude as a reflector of a lower start point of the eyelids (which may correspond with the subjective feeling of having heavy eyelids). In addition, a decreased saccadic rate was also associated with increased errors. This finding was interpreted as reflecting a general slowing of the arousal system.

### Ratings of sleepiness

Several rating scales have been used in relation to studies of driver sleepiness. However, the Karolinska Sleepiness Scale (KSS) is the only scale that has been validated in a driving context. KSS is a nine-graded scale (1 very alert and 9 very sleepy, difficulties staying awake, have to fight sleep) that refers to perceived level of sleepiness during the last 5 minutes (or a shorter time interval, (Åkerstedt & Gillberg, 1990)). Normally ratings are collected every 3–5 minutes in simulator studies. In field studies ratings are often collected less frequently (e.g. 1–2 ratings/hour) in order to restrict the interference with the driving task.

Horne and co-workers have shown in several studies that KSS ratings co-vary strongly with accidents and incidents in simulator studies (Horne & Baulk, 2004; Horne & Reyner, 1996; Reyner & Horne, 1998). Ingre et al. have shown that KSS ratings are strongly correlated with driver performance measures (standard deviation of lateral position and driving off the road incidents) and blink duration using data collected in the VTI simulator (Ingre, Åkerstedt, Peters, Anund, & Kecklund, 2006). Thus, it seems that rating of 7 (sleepy but no problem to stay awake) is a critical level. Below 7, physiological and behavioural signs of sleepiness are rare, whereas they increase considerably at the level of 8 and 9.

## 2.2 Fatigue on board

Working on a ship’s bridge means in most instances working irregular work hours, including night work. There are several categories of irregular working time arrangements, which have in common that they are used in order to make around-the-clock operations possible. There are negative effects of irregular work hours, which are mainly a consequence of two factors – the biological 24h-hour rhythm and sleep loss. The biological rhythm is stable and adaptation to, for example, night work is therefore slow (cf. also jet-lag). During the night most biological functions, e.g., metabolism, are slowed down, while they reach a peak during the day. The biological rhythm also affects mental functions. When awake during the night mental performance and alertness is low due to the biological rhythm. In addition the biological rhythm strongly affects sleep. Sleep during the night is easy to initiate and maintain for a sufficient time, while the opposite is true for sleep during the day. Hence, in connection with night work, sleep which precedes work might be short and sleep loss will be the consequence. The negative effects of sleep loss then add to the negative effects during the night time trough of the biological rhythm.

There is a considerable amount of scientific literature on the effects of such working hours on safety, productivity and health within other industrial settings. A special issue of Occupational & Environmental Medicine is devoted to the subject on a general level ("Fatigue at work," 2003), whereas other studies focus on transportation workers (McCallum, Sanquist, Mitler, & Krueger, 2003). Within the transport industry much interest has been directed to the effect of working hours (especially night work) on safety. For instance, two international symposia could be mentioned. The symposium “Work hours, sleepiness and accidents” was held in 1994 and the symposium “The sleepy driver and pilot” in 2000, both in Stockholm. During the 1994 symposium a consensus statement was formulated which strongly stresses the risks for accidents due to sleepiness/fatigue. The statement was later published in Journal of Sleep Research. Several studies show a markedly increased risk for accidents in connection with night work. A Swedish study showed that the risk for a single vehicle accident is 13 times higher than compared to daytime, and the risk for industrial accidents is doubled (based on Swedish accident data). A number of major industrial accidents have occurred during the night, for example the Three Mile Island, the Chernobyl, and the catastrophe in Bhopal. The grounding of Exxon-Valdez also occurred at night, and fatigue was considered as one of the important factors behind the accident.

The issue has been studied in the maritime industry, for example (Sanquist, Raby, Forsythe, & Carvalhais, 1997) and several studies and recommendations made by government agencies and institutions such as AMSA (1998), IMO (2001), MAIB (2004), Miller, Smith, & McCauley (1998), Rhodes & Gil (2002). There are literature reviews looking into definitions, effects and management strategies, in transportation in general (Boivin, 2000) and specifically for maritime operations (Gander, 2005).

A 1996 United States Coast Guard analysis of 279 incidents showed that fatigue contributed to 16 percent of critical vessel casualties and 33 percent of personal injuries.

The MAIB (2004) report showed that a third of the ship accidents that took place between 1994 and 2003, and which were subject to a MAIB investigation or preliminary examination, involved a fatigued officer alone on the bridge at night.

Fatigue at sea and related issues such as stress and overload are more important today than before. Ships' crews are under pressure from schedules and economy, and have to handle their tasks with an increasingly smaller number of crewmembers. There are several incidents and accidents attributable to fatigue, and the number may in reality be even larger than reported. For instance, a study performed by the Swedish Maritime Administration (SMA) in 2006 indicates this. As shipping is an international business, we believe this to be true for all countries, and perhaps some more than others. However, fatigue is not only a problem for ships flying a flag of convenience. Specialised routes may lead to suboptimal work schedules even on high standard ships, and the potential for catastrophic consequences with a fatigued watchkeeper in the wheelhouse is large.

There is also the recent and extensive study performed by Cardiff University (Smith, Allen, & Wadsworth, 2006). This study reports that many factors in combination must be considered to understand fatigue at sea, such as poor quality sleep, negative environmental factors, high job demands and high stress. Methods used in the Cardiff programme include questionnaires, diaries, vessel motion and noise measurement. A series of measurements were performed onboard, measuring mood, reaction time (N=22–49), focused attention and a search task. Actiwatches were used to assess quality and length of sleep (N=90–94), and cortisol levels (N=26–46) were measured. They studied the crew on one minibulker and compared it to other ships.

The U.S. Coast Guard performed a fatigue study in which crews on Coast Guard Cutters performed a series of cognitive and motor tasks. Decrements on some measurements of performance were found, such as lapses in vigilance and decreased pattern matching ability (Miller et al., 1998).

However, there are few other published results of field studies of maritime watchkeepers where physiological variables have been measured, except the almost 20-year old studies performed by Colquhoun and colleagues (Colquhoun et al., 1988). Methods which have been used earlier range from questionnaires, sleep logs and observations to accident analyses. Nonetheless, some issues have not been resolved – firstly there are indications that data collected through subjective methods such as questionnaires or interviews are not convincing enough as they may be perceived as biased or not entirely accurate. Secondly, recommendations for changes have not been effective. The shipping community may not be fully aware of the risks. In a closed voting session at a Swedish maritime day 73% of the participants (all maritime officers) admitted to having fallen asleep one or more times on watch (Lützhöft & Kiviloog, 2003). This shows that careful study planning with methods that guarantee confidentiality can gain disturbing, but accurate, results.

The Karolinska Institute (KI) has conducted several field studies onboard Swedish naval ships in cooperation with the Swedish Navy (Åkerstedt & Gillberg, 2004). The studies focused on subjective sleepiness and subjective sleep parameters during shorter missions. They studied "6 on, 6 off" schedules, both with traditional watch changes (00h, 06h, 12h, and 18h) and with changes displaced by 3 hours. Also studied was a three-watch system with three teams alternating, being 4 hours on and 8 hours off watch. An experiment in a ship bridge simulator studied subjective sleepiness during watches (6 on, 6 off system). To briefly summarise the results of these studies: levels of sleepiness are higher during the 00–06h watch as a whole (as compared to the other watches) and even rise towards the end. The levels of sleepiness recorded during the night, both in the field studies and the simulator study, reach those recorded during night work in connection with other work places, e.g., industries, road and rail transport. But we must not focus on direct effects of fatigue alone. Aside from the highly increased risk of accidents on a short-term scale, there is evidence that there are serious long-term health effects of fatigue and sleep deprivation. The whole body is affected, for instance the risk of cardio-vascular problems is increased, which is an already over-represented health problem in the mariner community. The mind is also affected, leading to stress symptoms, lack of concentration and memory degradation.

## 2.3 Background summary

Research shows that fatigue is a safety issue, in industries and in different traffic situations and particularly during the night. There is also a large risk for the short- and long-term health of those working in shift systems.

However, there are few studies measuring physiological variables at sea on any large scale, and none of them recent. Since the older studies were performed, crews have in many cases been halved, and workload therefore has increased. There are also indications that even as technology may have relieved crews of some workload, regulations may have added to it.

There is a lack of ‘hard data’ to support stakeholders in their decision-making, and a lack of recommendations tuned to the needs and constraints of the shipping business. Finding solutions to this problem is constrained from many perspectives: suggestions must not lead to significant extra costs for the concerned parties and stakeholders. The challenge is to find solutions that are effective, economical and easy to use for all involved.

# 3 Purpose

The project as a whole has an overarching purpose; to highlight the issue of fatigue at sea, and provide data and tools for relevant stakeholders to address the issue.

In this report, we describe and discuss results of the field study and the shipping company interviews.

The purpose of the field study was to collect quantitative data about the fatigue level of bridge watch keepers on board ships, using several methods and techniques. Specifically, we wished to measure possible differences between the 6/6 and the 4/8 watch system.

The main hypothesis of the study is: *shift system 6x6 induces **higher** sleepiness in the participants as compared to shift system 4x8*. The second main hypothesis is: *EOG mean blink duration values correlate positively with KSS scale.*

On a longer time-scale, one further purpose is to use the data corpus to refine the Karolinska Institute mathematical model SWP (Sleep/Wake Predictor),

The purpose of the interviews was to discuss with persons in leading positions in shipping companies and shipping agencies their attitude towards fatigue and fatigue monitoring.

We wish to use these results and earlier work to devise innovative solutions for the shipping industry. The ultimate purpose is to construct solutions that lead to safe manning of ships while acknowledging economical constraints. A collection of recommendations, relevant for various stakeholders, will be published separately.

# 4 Method

This chapter presents and discusses the methods and techniques chosen in this study. Firstly, the field study design, participants, methods and techniques is presented. The preparation of the EOG data is discussed. This is followed by a presentation of the interview study design.

## 4.1 Field study

### 4.1.1 Design of study

The design of this study was a within-subject non-experimental study, where measurements took place at the participants' actual workplace and within their ordinary working hours. Due to the low number of participants, the approach was that of a qualitative study, where each participant was his/her own control. There was however the objective of comparing the two watch systems.

The data collection was performed during visits onboard 13 cargo vessels of different types, such as bulk carriers, car carriers and tankers.

To ensure the measurement procedure before the start of the data acquisition, pilot studies were conducted on two ships, one small archipelago passenger vessel and one large passenger cruise ship. The purpose of the pilot studies was to ensure that the measurement procedure did not interfere in an inappropriate way with the participants' working routines. Furthermore, we wished to ascertain that the measuring equipment used did not interfere with the bridge electronic equipment, nor that the bridge electronics would disturb the data recording. Neither of these effects was detected in the pilot studies. Although this equipment (Embla/Vitaport) is often used in hospital environments where for instance ether and oxygen would be expected to be present, we could not attain a 100% guarantee that the equipment was explosion safe. Therefore, when we performed measurements on tankers, the participants did not wear the equipment on deck or outside the accommodation. A further purpose with the pilot studies was to familiarize the test leaders with the procedures and the equipment.

### 4.1.2 Participants

Choice of participating companies was done on an availability basis. Earlier contacts with shipping companies had shown those positive to participating in research projects. They were also chosen to constitute a good variation in ship and watch type. Ships were chosen in cooperation with the companies, based on availability and willingness of all watch officers to participate. To some degree, we considered trade and time of voyage and thus the possibility to join and leave ships at convenient locations. Originally there were 32 participants in the study, but due to loss of data only 30 were included in the study (29 males and 1 female), with a mean age of 41.5 years (SD=9.9) and a mean experience time of watch going work of 20,1 years (SD=11.6). The onboard visits had durations between 2 to 7 days, and the size of the vessels varied from 2,300 to 11,000 dwt. Prior to the visits, participants were given information about the study by e-mail sent to the company and the ship, see Information about the study, and verbal consent was given for participation. Written consent for participation in the study was given to the test leaders at the beginning of the onboard visit.

### 4.1.3 Watch systems

Two watch systems were included in this study; the two-watch 6 on/6 off and the three-watch 4 on/8 off systems. The two-watch vessels can be divided into two groups, where the first had two watch keepers sharing the watches (pure 6-6), and a watch-free captain who was not involved in the 6 on/6 off system (called here 6-6+1). The second group consisted of those vessels with one mate and the captain sharing the watches. The three-watch vessels (4 on/8 off) had three watch-going mates and one captain. See Table 1 below for the participant distribution in the two watch systems.

*Table 1 Participants and watch systems.*

| Participant number | two-watch | | three-watch | | |
|---|---|---|---|---|---|
| | 00–06<br>12–18 | 06–12<br>18–24 | 00–04<br>12–16 | 04–08<br>16–20 | 08–12<br>20–24 |
| 1 | | X | | | |
| 2 | X | | | | |
| 3 | X | | | | |
| 6 | | X | | | |
| 7 | X | | | | |
| 8 | | X | | | |
| 9 | X | | | | |
| 10 | | X | | | |
| 11 | X | | | | |
| 12 | | X | | | |
| 13 | X | | | | |
| 14 | | | | | X |
| 15 | | | X | | |
| 16 | | | | X | |
| 17 | | | | | X |
| 18 | | | X | | |
| 19 | | | | X | |
| 20 | | | | | X |
| 21 | | | X | | |
| 22 | | | | X | |
| 23 | | X | | | |
| 24 | X | | | | |
| 25 | | | | | X |
| 26 | | | | X | |
| 27 | | | X | | |
| 28 | | X | | | |
| 29 | X | | | | |
| 30 | | | | | X |
| 31 | | | | X | |
| 32 | | | X | | |

### 4.1.4 Choice of measurement techniques

There is no standardized methodology for the recording of sleepiness. However, as mentioned in the background, five recording techniques have been commonly used; recording of EEG and EOG, camera recordings, behavioural signs of sleepiness, driving parameters associated with performance impairment and subjective ratings of sleepiness. We discuss here the choices made for the field study. One aspect we had to accommodate was that the participants must be able to walk around, as officers commonly do during their watch. This meant that no cables attached to e.g. computers could be used. It also meant that no recording using a panel-based or fixed technology (e.g. a camera) could be used. Thus, the equipment had to be portable and not too disturbing. Also it had to be possible to attach and detach the equipment in a reasonably short time. We did not want to impose significantly on the free time of the participants as this would disturb the study, nor could we do anything which would divert their attention during their watch.

- One technique is based on the recording of EEG (electrical brain waves) and, in most cases, EOG (eye movements). EMG (muscle tension) may also be used. In the case of the field study, we used EOG. According to experts, EEG is too sensitive when participants move about and EMG is not useful in an uncontrolled field setting.
- Another common technique that has received a lot of attention is camera-based eye movement recordings. This method was not used, again in order not to restrict the movements of the officer on the bridge.
- A third technological category refers to observing behavioural signs of sleepiness, such as body movements, gestures, facial tone and head movements. This technique was not feasible, since it would either need an observer on the bridge, which would disturb the study, or some type of recording for later analysis, which would mean the operator, would have to stay reasonably still, and not walk around.
- A fourth category refers to driving parameters associated with performance impairment during sleepy driving. This was not used due to the impossibility of controlling the driving/ navigation task.
- A fifth category refers to subjective ratings of sleepiness. The KSS (Karolinska Sleepiness Scale) was used for this purpose. This scale is well-used and validated.

Four types of instruments were chosen for data collection; questionnaires and diaries, eye movement measurements, activity meters and reaction time tests. They were chosen to ensure useful objective and subjective measures without disturbing the normal routines of the participants. A summary of methods and measures is shown in Table 2.

*Table 2 Instruments and measures used.*

| Instrument | Measure | Variable |
|---|---|---|
| Questionnaire | Health questions | Subjective health |
| Sleep diary | Sleep duration & quality | Subjective sleep length and quality |
| Actiwatch | Acceleration | Objective sleep length and quality |
| Awake diary | Watch times, KSS | Subjective sleepiness |
| EOG | Eye blinks | Objective sleepiness |
| Reaction time | Reaction time | Reaction time differences |

**Questionnaires and diaries**

In the beginning of the onboard visit, a questionnaire concerning general health was introduced to the participants, see Appendix 2. This included questions about home conditions, health issues, sleep habits etc. Sleep quality was measured by handing out sleep diaries, to each participant, see Appendix 3. The sleep diary was filled in after each period of sleep, including sleep on daytime off-duty periods. The sleep diary has been validated against EEG (Åkerstedt, Hume, Minors, & Waterhouse, 1994).

Subjective sleepiness estimations were performed by the participants once an hour they were awake, using the Karolinska sleepiness scale, KSS, a scale from 1 to 9, where 9 is the highest level of sleepiness. Participants were at the same time asked to rate their level of experienced stress, on a 9-point scale, similar to the KSS. The wording for each scale step was provided on each diary sheet so that the participant easily could connect the scale steps to a certain sensation. See "Awake Diary onboard" for the Awake Diary where also the scales are shown.

**Eye movement behaviour (EOG measurements)**

EOG (Electrooculography) is a method to record eyeball movements using equipment commonly used in psychophysiological laboratories. The basis is the electrical potential difference between the front and back of the eye (Andreassi, 2000). EOG is a suitable tool for objective characterization of drowsiness (Galley & Schleicher, 2002). For example, an increase of blink duration lengths is related to higher KSS levels in controlled environments, (e.g. a driving simulator) (Ingre et al., 2006). Depending on the type of eye movements to record the electrodes are placed differently. For detection of horizontal motion there is generally one electrode at the outer edge of each eye which gives a binocular recording. Monocular recording is also possible and accomplished by placing electrodes at the inner edges as well. With electrodes above and below the eye vertical movements are measured. Vertical recordings are usually monocular since the eyes move synchronously (Andreassi, 2000; Stern, Ray et al., 2001). The cables are placed so that they do not disturb the test person or can be torn off unintentionally by body movements. The placement of electrodes for horizontal and vertical EOG as well as for EMG is shown in Figure 1.

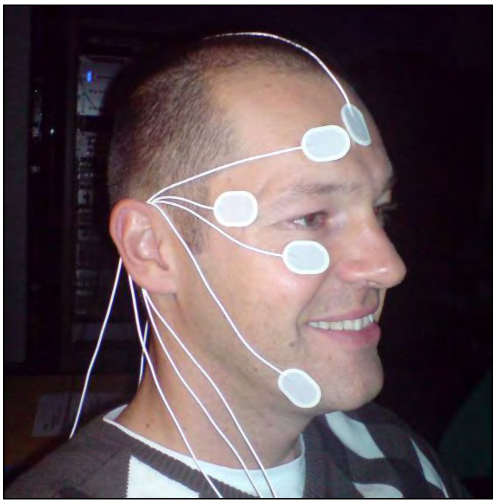

*Figure 1  Electrode placement for measuring EOG and EMG.*

In the field study EOG was measured with electrodes placed at five places around the eyes of the participants, ground was placed in the forehead. The technique was used to record eye movement behaviour in the horizontal and vertical directions. Furthermore, in the beginning two optional electrodes were used to record facial EMG, meant for distinguishing of artefacts in EOG data, yawning for example. However these were left out on later trips to shorten application time and since there was no plan of analysing those signals. Disposable electrodes were used to make the application as fast and easy as possible. To ensure an appropriate conductance the skin was rubbed with electrode paste before placing the electrodes, see Figure 2.

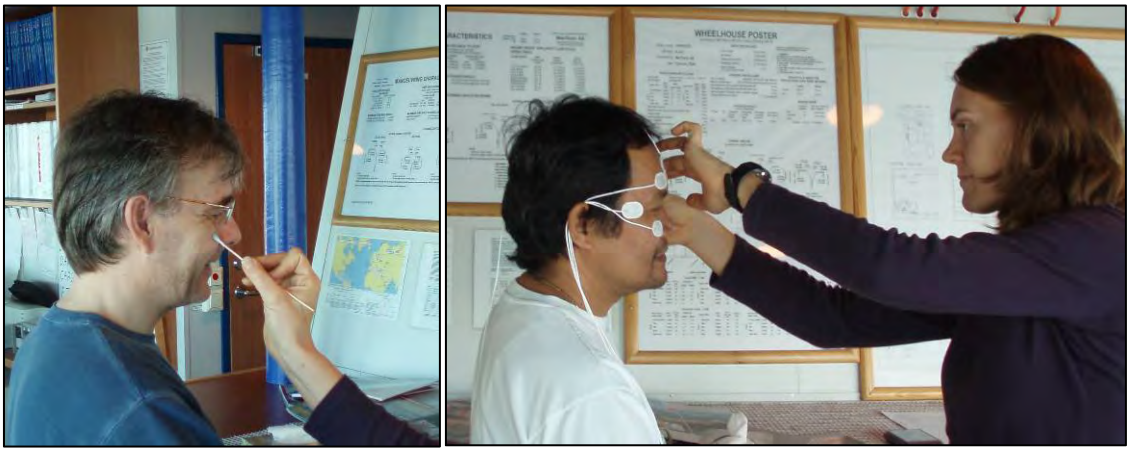


*Figure 2  Preparation for and placement of electrodes.*

The EOG and EMG electrodes were during the first 7 trips connected to an ambulatory medical recorder called Embla (Flaga hf. Medical Devices, Reykjavik, Iceland) rented from the Karolinska Institute. On the 6 later trips VTI's medical recorder VITAPORT from TEMEC was used instead. The use of different recorders has no influence on data when it comes to the analysis. The advantage of using the VITAPORT is that it allows the test leader to ensure data quality by looking at the signals online, while onboard. Both medical recorders were placed in a bag and carried in a belt around the waist, over the shoulder or where most comfortable, see Figure 3.

*Figure 3 Participant with Vitaport equipment.*

In this study, EOG and EMG were recorded during the participants' watches. For every onboard visit, at least two series of physiological data from each participant, including one daytime and one night watch, were recorded. As maximum four data series were recorded on each participant on one trip. The variation in number of data series on any one trip depends on the number of days onboard but also on the number of days in the open sea. There were no measurements on watches during arrival to and leaving ports.

**Activity meters (Actiwatch)**

At the first opportunity during the onboard visits, as the project was presented and questionnaires handed out, an Actiwatch was issued to each participant. Subjects were instructed to wear them during the entire onboard visit, except when showering. The Actiwatch is a small wrist-watch-type device which measures acceleration, see Figure 4. By measuring acceleration at the wrist, a measure of physical activity can be retrieved and from that an activity pattern for a participant can be produced. In this study, this measure was used for determining objective quality of sleep and to complement the subjective sleep quality estimates from the sleep diaries. Also, length of sleep can be retrieved from Actiwatch data.


*Figure 4  Actiwatch placed on wrist.*

**Reaction time test**

Since the field study is performed in an environment that is not controllable, any direct measures of performance derived from the actual task, which in this case is the tasks of the participants' workplace, is difficult to receive. Instead, to get some measurement of performance, a reaction test was given to the participants. This test lasts for a predefined time, in this case six minutes, and is performed on a Palm handheld computer, see Figure 5. Every time a black square occurs on the screen the participant responds by pressing a key. All participants answered 60 times. The purpose of the reaction test was to examine any difference in performance after daytime watches and night time watches. If this was to be performed during the watch, it had to be relatively brief in order not to disturb the watch-keeper. If it was to be performed after the watch, it had to be brief, in order not to take too much of the free time of the watch-keeper. Ten minutes is a lot of time in this context, but is generally recommended (Lisper & Kjellberg, 1972). We chose to make it 6 minutes supported by earlier research in the field (Axelsson, Kecklund, Åkerstedt, & Lowden, 1998).

*Figure 5  Palm used for reaction time test.*

## 4.2 Interviews

The participants for the interview study were chosen from a list of Swedish shipping companies. Those with one or very few ships were removed from the list. Twenty-four companies were then called on the telephone and asked to participate in the study. Thirteen of the 24 companies participated in the study (see Table 3). Two of the companies that participated in the study were shipping agencies and the remainder were shipping companies. Three of the participating companies had crew members both from Sweden and from other countries.

Three of those who declined participation were not responsible for crewing (one of them had crew from the Philippines, the other two from Swedish shipping agencies). Eight of the companies did not have time to attend the study.

The following Swedish shipping companies and shipping agencies participated in the study: Broström AB, Donsötank Rederi AB, Furetank Rederi AB, Gotland Rederi AB, OSM Ship Management AB, Sirius Rederi AB, Stena Marine Management AB, Stena Rederi AB, Tarbit Shipping AB, Transatlantic Rederi AB, Walleniusrederierna AB, Wisby Tankers AB and Österströms Rederi AB.

*Table 3 Information about participating companies.*

| *Id no* | *Number of crew members* | *Number of Vessels* |
|---|---|---|
| 3 | 753 | 25 |
| 4 | 450 | 17 |
| 5 | 118 | 5 |
| 6 | 120 | 7 |
| 8 | 90 | 5 |
| 9 | 240 | 7 |

| *Id no* | *Number of crew members* | *Number of Vessels* |
|---|---|---|
| 12 | 650 | 0 |
| 15 | 200 | 10 |
| 16 | 1,700 | 12 |
| 18 | 101 | 6 |
| 22 | 650 | 22 |
| 23 | 34 | 2 |
| 24 | 46 (only Swedish) | 3 |

Since it was unlikely that most shipping companies would spend time on filling out a questionnaire the approach was an interview by telephone. First we made phone calls to the companies and informed them about the study and asked them if they would like to participate. An appointment was made for a telephone interview with those who wished to participate. The next step was to e-mail the information about the project and the questionnaires. The interview was performed in Swedish. The questions are based on a questionnaire from an EU-project called SENSATION which was complemented with questions specifically of interest for the fatigue at sea study. The following questions were asked:

- General questions about the company. Number of employees, number of vessels, type of vessels and type of company.

- How many employees on board on your ships have tasks that might be sensitive to fatigue/sleepiness?
- Is this a problem? If yes, for whom?
- Do you take actions to decrease this problem?
- Do you have systems on board or on the bridge that may be sensitive to interference by electronic equipment? If so, what kind of systems/equipment?
- If available, would you consider it worthwhile to ask employees to carry fatigue monitors to increase safety and well being? Please give reasons for yes or no.
- Do you think it likely that monitoring devices would be accepted by the employees? If not, why?
- If worthwhile, would you be willing to buy such equipment? If not, why?
- What might be an acceptable cost for such equipment per employee?
- If using fatigue monitoring equipment would be connected to, say, a 30% reduction of insurance fees, would that make it interesting to use such equipment? If not, why?

The answers were written down and for the analysis, in a few instances grouped into similar basic answer categories, where appropriate. For example, we group and count those positive or negative to a certain question. Almost all of the answers are presented verbatim (translated from Swedish) in the results section. A few answers were removed, but only those not relevant to the question asked.

# 5 Data analysis

This section describes how data were prepared for analysis and how the data were analysed. Generally, a significance level of P=0.05 is used in this analysis.

## 5.1 Health questionnaires

21 health questionnaires were returned and analysable. Since there is a variance in amount of data for each person and each type of measure, the analysis method was not obvious. Here, two different methods were used interchangeably. The first includes all values from the diaries and no concern is made about who has answered and how many times. In the second, mean values for each person and each question was calculated before further analysis was made.

## 5.2 Sleep and awake diaries

The mean values of KSS (Karolinska sleepiness scale) and stress scores from the diaries, for each participant and every hour was calculated both from the *on board* ratings and for the *at home* ratings. These were then compared for the two watch systems. For the KSS values at bed time and get up time a qualitative data overview was made, with no concern for how many times a certain person filled in a diary.

## 5.3 EOG, KSS and stress data

### 5.3.1 Preparation of EOG data

Electrooculogram (EOG) data was collected by a Vitaport II[1] digital data recorder and EMBLA[2] physiological data recorder. The sampling frequency of the EOG vertical and horizontal channel was 512 Hz, which was necessary for the blink extraction algorithms. From the raw data to analyzable data several steps were necessary: First the data was screened for recording or electrode-placement errors, this was a simple visual control to ensure data validity. Then the raw data files were converted into EDF files (European Data Format[3]). Data parts were cut out for calibration in the next steps. The EOG eye blinks were automatically detected via a Matlab program developed by LAAS[4] and modified at VTI Sweden, see Figure 6. The performance of the blink-extraction software was controlled afterwards. The result was a list of EOG features for further processing. The blink data was further processed to obtain 10 minute running mean values, and screened for outliers. The main physiological variable of interest was the running 10 minute mean of the blink duration (calculated from 50% raise to 50% fall in amplitude). The blink duration values were then synchronized with the KSS data and the stress data scorings, in order to allow statistical analyses. All data was entered into an SPSS database, which also contained all relevant data about the participants, shifts, times, etc.

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[1] TEMEC Instruments, Netherlands: www.temec.com.
[2] EMBLA USA: www.embla.com.
[3] European Data Format webpage: www.edfplus.info.
[4] LAAS – Laboratoire d’Analyse et d’Architecture des Systemes. www.laas.fr.

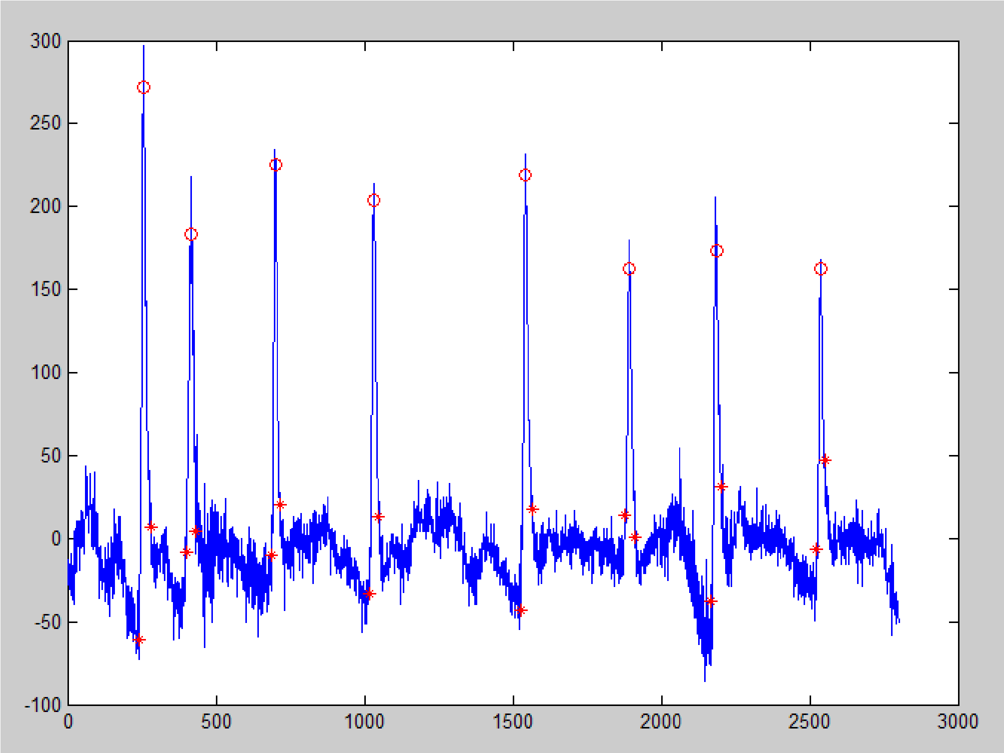


*Figure 6 Example of EOG blink extraction; x-axis shows a 30-seconds time period, y-axis is amplitude in milliVolt. The typical form of EOG eye blinks is clearly visible, as well as some noise in the data. Eye blinks are marked with red circles, start and stop of the blinks with red stars.*

### 5.3.2 Algorithms for EOG data preparation

Here, selected steps of the EOG data preparation are illustrated, since basic signal processing methods are not of interest. The EOG blink extraction included the following (shown in Figure 7):

- PERCLOS P80 for windows of 20 seconds
- Start position of blink
- The moment when the eyelid finishes closing
- The moment when the eyelid begins opening
- End position of blink
- Blink duration calculated from the start position of blink to the end value of blink
- Blink duration calculated from the half rise amplitude to half fall amplitude
- Peak position of blink
- Amplitude calculated from start of blink complex to peak of this blink
- Lid closure speed
- PCV (peak closing velocity)
- Lid opening speed
- Peak opening velocity
- Delay of eye lid reopening

- Duration at 80
- Closing time
- Opening time.

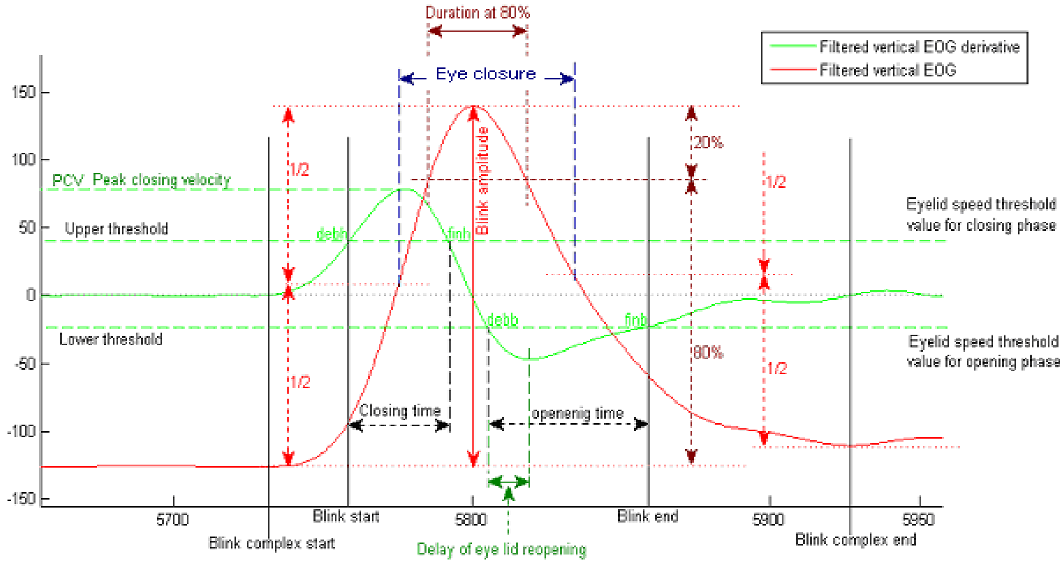


*Figure 7 EOG extraction parameters.*

The main steps for EOG blink extraction were the following:

- Filter data.
- Compute derivate of data.
- Apply thresholds on EOG derivative to localize eyelid movements.
- “Normal” amplitude blink validation.
- Test the possibility of gathering continuous blinks.
- Apply constraints to ensure computation validity.
- Save extracted parameters.

The EOG blink extraction procedure was labour intensive, and EOG data of low quality was a problem for some participants. Manual EOG scoring would have been too demanding, given the length of the recordings. In the analysis only data found to be of reliable quality were used.

The relationship between sleepiness scores and shift system, time of day, EOG values, and other factors of interest are studied. Stress scores are also analyzed, and a relationship with long work times and time of the day is expected. Situations where very high sleepiness scores are registered are of special interest. The main hypothesis of the study is: *shift system 6x6 induces **higher** tiredness in the participants as compared to shift system 4x8*. The second main hypothesis is: *EOG mean blink duration values correlate positively with KSS scale.* KSS scores are taken as the primary reference for tiredness of participants. A similar analysis as for the KSS scores was performed on the stress scores.

The data analyzed included for each participant[5]:

- Date of shift worked
- Time of day of shift worked
- Sequential number for each shift worked
- Hours worked on each shift (numbered sequentially)
- KSS score (scored once each hour when on shift)
- Stress score (scored once each hour when on shift)
- Mean blink duration (calculated for the 10 minutes before scoring KSS)
- Shift system of participant
- Planned shift duration (from hh:mm to hh:mm)
- Job position
- Reaction time scores.

The amount of available data was much higher for KSS data than for EOG data. 15 participants worked in the 6x6 shift system (10 in 6x6 and 5 in 6x6+1), and 15 in the 4x8 system. The total number of KSS scorings for all participants is close to 1,500, and data for EOG mean blink duration is only present in 28.3% of those cases. Some diaries were filled in before or after the researcher were on board. The number of KSS scorings and EOG mean blink duration values per subject are not equal, some subjects had many KSS recordings, others only a few. The reason for this is simply that some subjects filled in the KSS in the diaries for a longer period of time than others.

To improve statistical "veracity" of the analyses, controlling variables such as sequential shift number were used when appropriate. This can for instance mean choosing partial correlations analyses instead of bivariate correlation analyses. Furthermore mean scores or ranks were calculated for each participant and then analyzed in order to overcome the problems mentioned above.

One of the main independent variables of interest is the shift system. Each working shift was supposed to last 4 hours for the participants in shift system 4x8 (followed by 8 hours of free time) and 6 hours for participants in shift system 6x6 (followed by 6 hours of free time). The shift systems are shown graphically in Figure 8. Two types of 6x6 ships were present in the study, one where only two watch keepers (mate and captain) work on board and one where two mates are complemented with a watch-free captain. In the database the latter ships are referred to as shift system 2+1 (or 6x6 +1). On the 4x8-system three watch-keeping officers divide the 24 hours of the day between them. On those ships there is also a watch-free captain.

KSS values were scored by the participants at each full hour. In the analyses the KSS scores reported during time on watch are of interest, but overtime has been included in a few instances. The KSS scores range from 1 to 9, with 1 being "*extremely alert*" and 9

[5] The shifts referred to are, unless otherwise stated, the shifts which were worked while the researcher was on board.

being “*very sleepy, finding it difficult to stay awake, fighting against sleep*”. See Awake Diary onboard for the KSS scale.

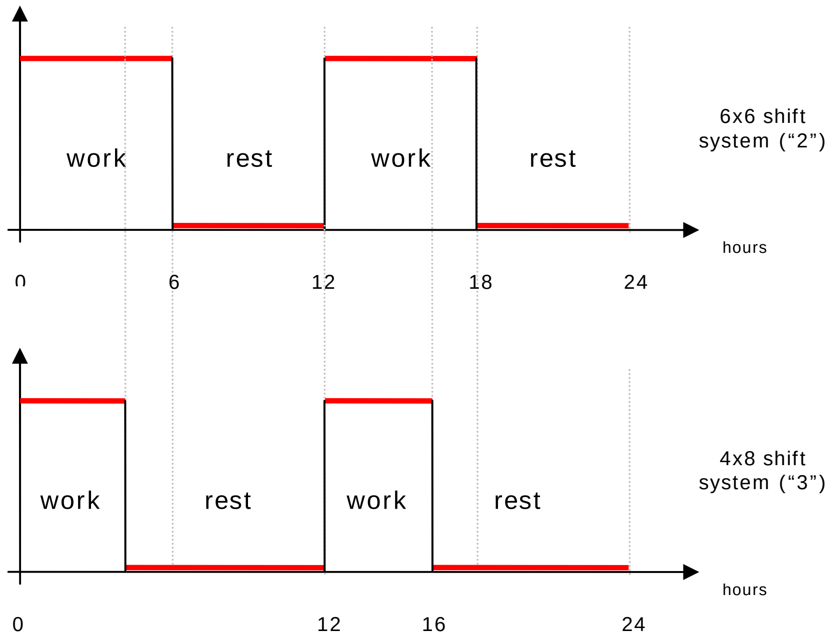


*Figure 8  Shift system graphical representation with working and rest hours.*

## 5.4 Data overview

First an overview of the available data is presented. In order to choose proper statistical tests, information about group size, distribution, missing values, etc, is relevant. The distribution of the variables is shown below. Participant “7” had more KSS scorings than the other subjects (Figure 9), however, when using only the occurrences where EOG data was available together with KSS scores this evens out. Shift system 6x6 was present as often as 4x8. For most participants KSS scores were recorded during 8 shifts (median value). The time of day for which KSS data was registered was distributed evenly, except a peak around 12:00 (Figure 10). Shift system distribution is shown in Table 4.

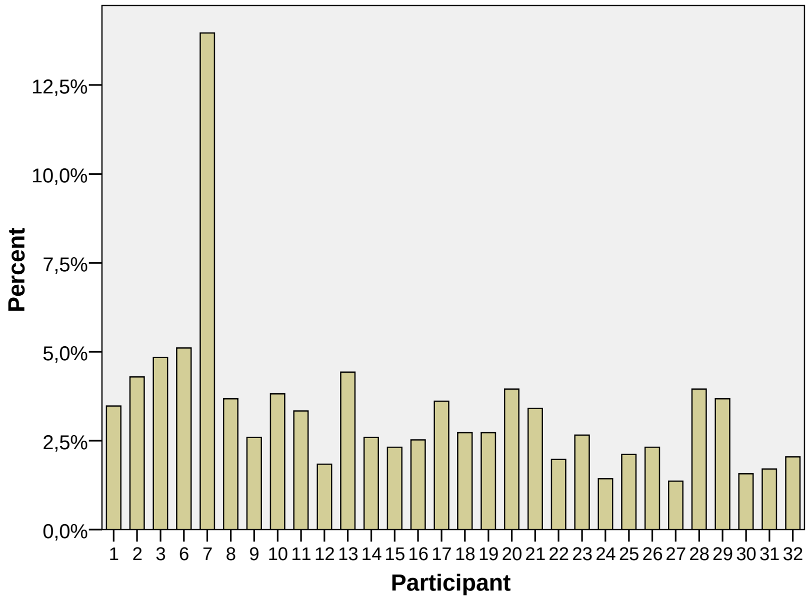


*Figure 9  Amount of KSS data available (% of total amount). P. 7 has more data available (see explanation above).*

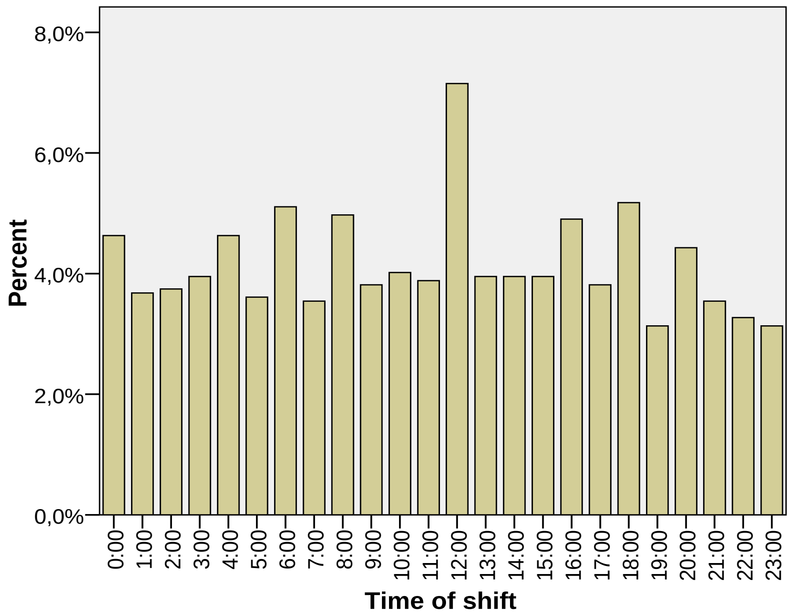


*Figure 10  Distribution of KSS data plotted by time of day when scored (% of total amount).*

*Table 4  Shift system distribution (frequency) for participants with valid data.*

| **Shift system** | No. of participants |
|---|---|
| 6x6 | 10 |
| 6x6+1 | 5 |
| 4x8 | 15 |

The distribution of nationality and professional position is shown in Figure 11 and Figure 12. The distribution of job position, time of shift and nationality is not equal for the participants, as the plots show. However, the distribution of shift system (6x6 against 4x8) is equal. To know what statistical approach to choose, the distribution of data is investigated: None of the data of interest are normally distributed (Kolmogorov-Smirnov tests at 0.05 level). This means that data transformation or non-parametric tests which do not require normal data distribution are needed for statistical analyses; non-parametric tests (distribution free methods) are the first choice here. Data from the main database was extracted and put into a new database where each participant is a case, here the variable distribution was approximately normal for the variables of interest.

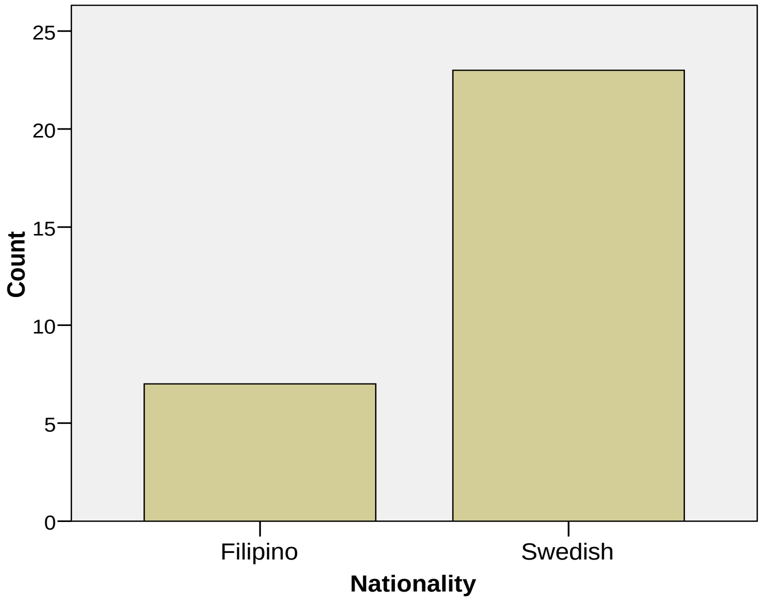


*Figure 11  Nationality of participants.*

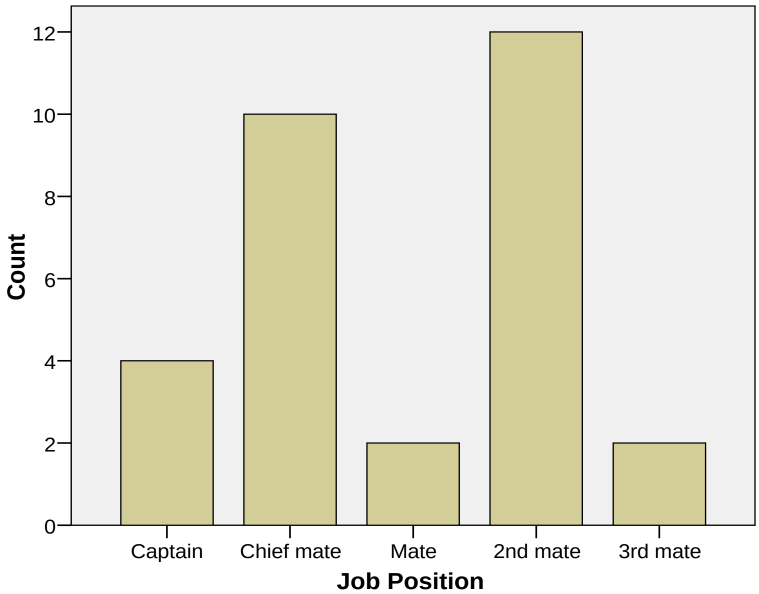


*Figure 12  Job position of participants.*

In order to analyze the reaction time data more in depth, a hierarchical linear model (mixed linear model) was used: the procedure is similar to a repeated general linear model, but with advantages when it comes to missing values as was the case in our study. The goal was to study the effect of other factors such as shift system (6x6 or 4x8) on the reaction time data.

## 5.5 Actiwatch

First, an automated analysis was made of the activity record, using the software Cambridge Neurotechnology Ltd. Activity and Sleep Analysis 5. Also using this software, corrections were made, removing awake or restless periods. A manual inspection was performed to identify periods that were uncertain, i.e. an inactive period after awakening often meant the Actiwatch was removed for showering, not another sleep period. This could be checked using watch times for the participants.

# 6 Results

The results are presented in two sections, first the results of the analysis of field study data, then the results of the interviews with shipping companies. The results are not discussed in this chapter. For this, the reader is referred to the discussion and conclusions chapters.

## 6.1 Field study

This section presents the results of the field study on board Swedish ships. First, the results from questionnaires and diaries are shown, followed by EOG, KSS and stress data analysis and results. At the end of the section reaction time results are presented.

### 6.1.1 Questionnaires and diaries

In this chapter the results so far from the questionnaire and diaries are presented. There are great possibilities to analyse the questionnaires and subjective ratings in more detail. See Appendix 2 for the health questionnaire, Appendix 3 for the sleep diaries and Appendix 4 for the awake diaries. The questionnaire was answered once, the diaries were filled in several times, all according to the good will of the participants. Twentyone health questionnaires were returned and analysable.

**Background information**

The general health seems good among the participants according to their own reporting in the health questionnaire. No special health problems were reported. The subjectively judged health conditions for both watch systems are shown in Figure 13. For the two-watch system 9 participants answered this question, 3 of which judge their health to be very good, 5 pretty good and one answered tolerable. For the three-watch system, 12 participants answered the question and the ratings are higher, 8 judge their health to be very good, 5 pretty good and one tolerable.

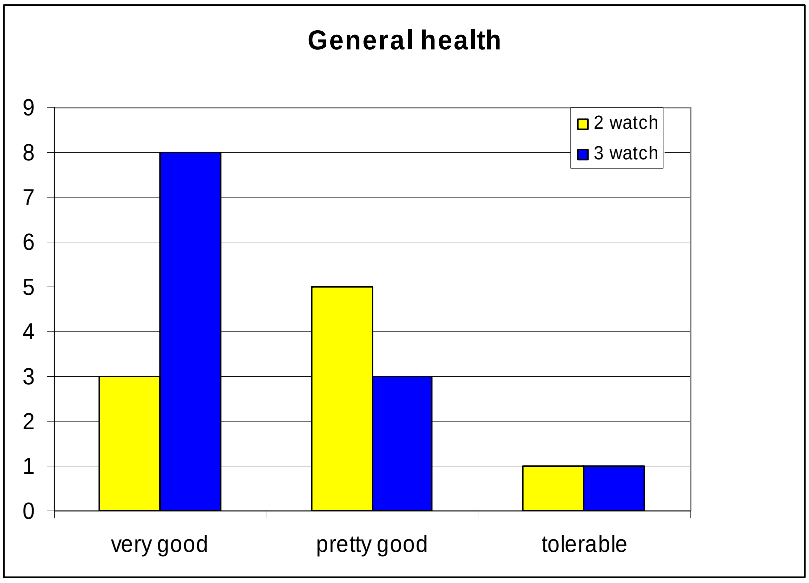


*Figure 13 Participants' self-reported general health.*

The questionnaire included questions about satisfaction with the working situation. Here also, the watch systems were compared (Figure 14). Mean values for each watch system was calculated. No significant difference was found ($p=0.05$) but tendencies indicate that participants in the three-watch system (N=12) are more satisfied with their working hours and working situation than participants in the two-watch system (N=9). Both watches are similarly satisfied with their working tasks.

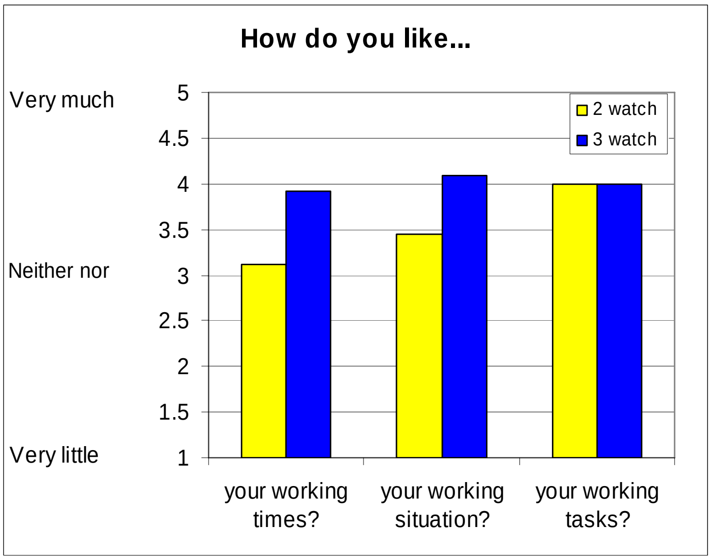


*Figure 14 Participants' satisfaction with their work.*

Background questions about sleepiness during the day were asked to get an idea of how sleepy the participants feel in general, see Figure 15. Also here mean values for the two watch systems were compared. No significant differences were found but tendencies suggest that participants in the two-watch system (N=9) more often get less than 6 hours sleep a day, more often nod off and more often fight against sleep than participants in the three-watch system (N=12).

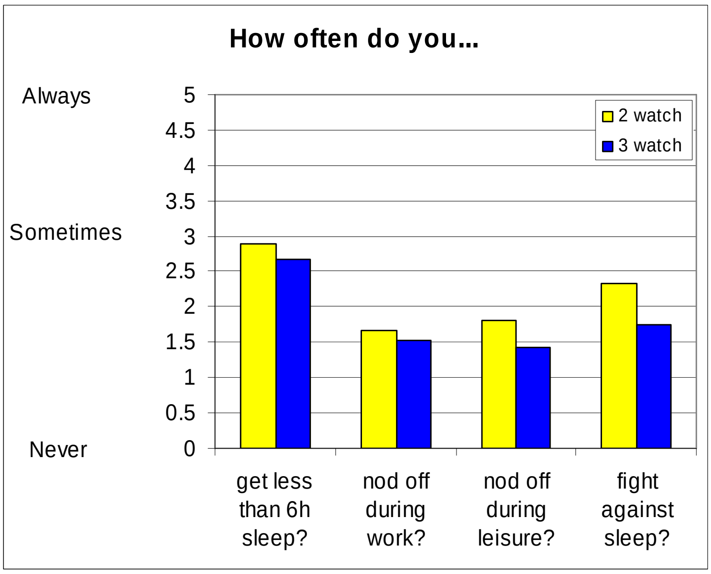


*Figure 15 Participants' self-rated sleepiness.*

When asked to judge how much sleep the participants need, the answers for both watch systems are very similar. The median values for both systems are eight hours a day meaning most participants think they need at least eight hours sleep a day. The mean values for each watch system suggests that the participants in the two-watch system (N=9) think they need slightly less sleep (7.03 h) than the participants in the three-watch system (7.43 h). No significant difference was found. See Figure 16 for self-rated sleep need.

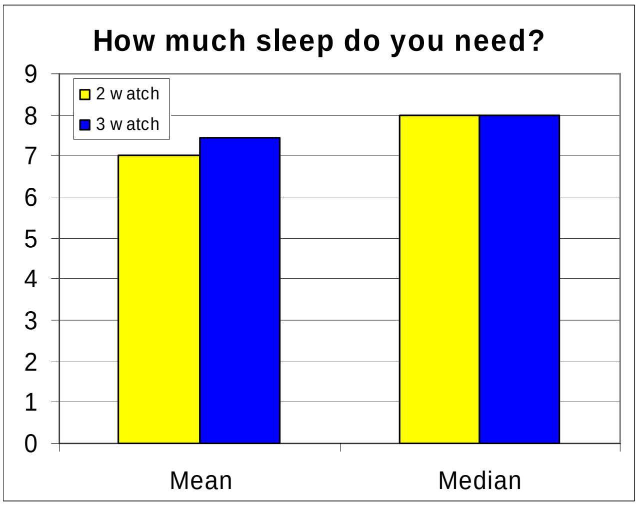


*Figure 16  Participants' self-rated sleep need per day.*

### KSS and Stress

The mean values of KSS (Karolinska sleepiness scale) and stress scores from the diaries were compared for the two watch systems, see Figure 17 and Figure 18. No significant differences were found, but tendencies suggest that the participants in the two-watch system is a bit more tired, especially in the early morning and in the afternoon, whereas the stress level is about the same. The mean values also indicate that both watches are less sleepy and less stressed at home than on board.

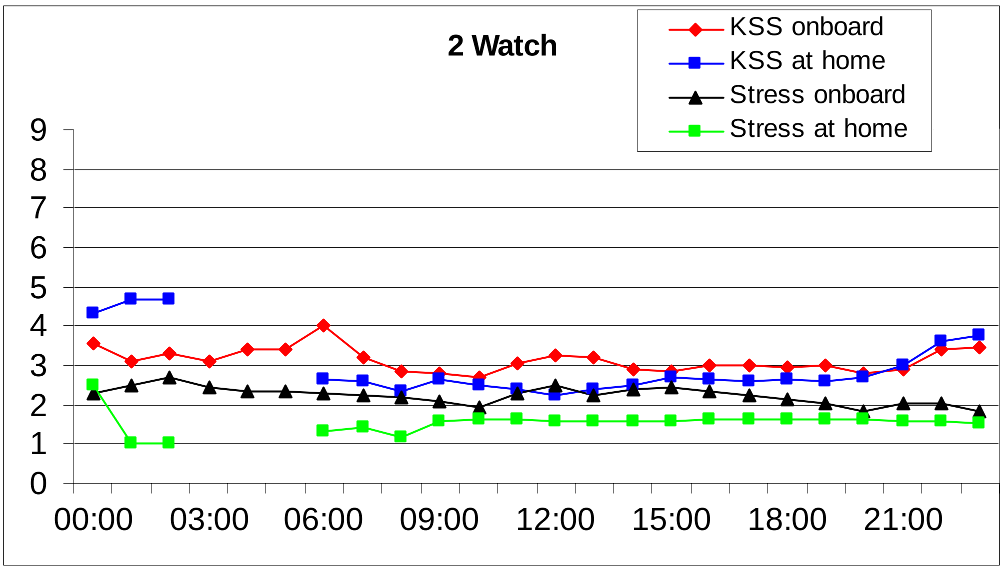


*Figure 17  Mean values for KSS and stress at home and onboard for two-watch.*

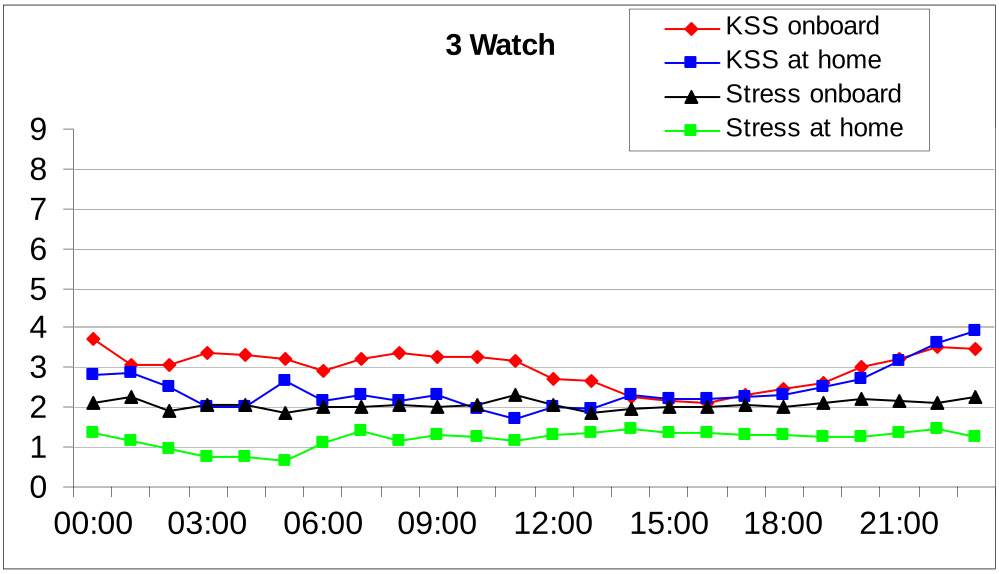


*Figure 18  Mean values for KSS and ESS at home and onboard for three-watch.*

For the KSS values at bed time and get up time a qualitative data overview was made, with no concern for how many times a certain person filled in a diary. The results indicate that participants are more tired when going to sleep at home than on board and also more rested when getting up at home than on board. This seems reasonable since they can choose time and length of sleep better at home, see Figure 19.

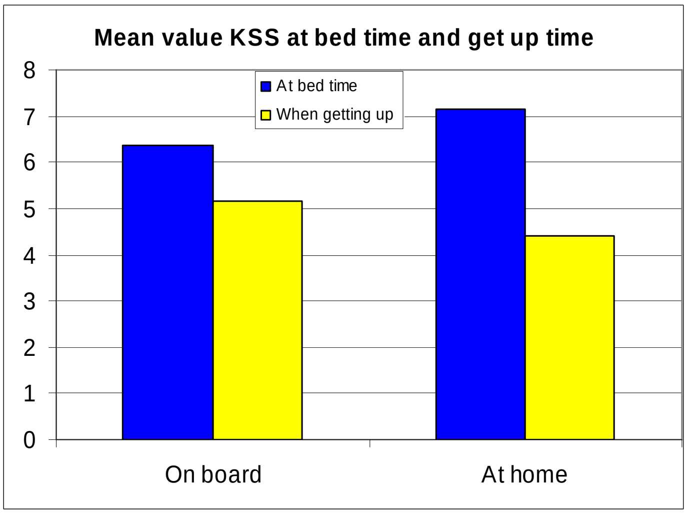


*Figure 19  Mean values for KSS at bed time and get up time for all participants.*

**Sleep quality**

Sleep quality and sleep length on board and at home were also compared from the total ratings given by both watches. The participants rated their sleep quality on a five graded scale where 5 are *very good* and 1 is *very bad*. Sleep length was also reported on a five graded scale where 5 was *yes, definitely enough* and 1 was *no, definitely not enough*. Tendencies show that both sleep quality and sleep length is better at home than on board but no significant difference was found, see Figure 20.

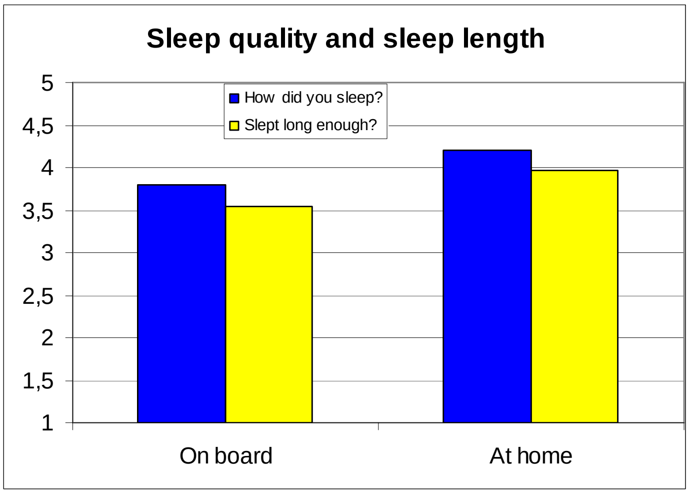


*Figure 20 Self-rated sleep quality and sleep length.*

### 6.1.2 EOG, KSS and stress data

In this section the results of the statistical analyses on the collected data are presented. How the EOG data was prepared and pre-processed is explained in sections 5.3. Here the data of each work shift for all available participants in the on-board studies is analyzed by statistical means, the focus is on blink duration measures and sleepiness scale. Results of the reaction time tests are also reported here. Situations where very high sleepiness scores are registered are of special interest. The main hypothesis of the study is: *shift system 6x6 induces* ***higher*** *sleepiness in the participants as compared to shift system 4x8*. The second main hypothesis is: *EOG mean blink duration values correlate positively with KSS scale*. KSS scores are taken as the primary reference for sleepiness of participants.

### 6.1.3 KSS distribution

KSS data was analyzed to get a first impression of the sleepiness ratings of the participants in the study. The following table and graph show basic data concerning KSS, only KSS data scored during working time was analyzed. Extreme values of KSS score 8 or 9 were present in 39 cases (of a total of 1468 valid scorings), but these occurrences were for 5 participants only (three in shift system 6x6, and two in shift system 4x8). Most common was the KSS score “3”. Mean KSS score was 3.97±1.505 (SD) with range from 1 to 9, median value was 4. KSS score distribution is presented in Table 5 and graphically in Figure 21 and Figure 22 (with box plot and normal curve).

*Table 5 KSS distribution for all participants (data from Figure 23).*

| KSS-Score | Frequency | Percent |
|---|---|---|
| 1 | 33 | 2.2 |
| 2 | 150 | 10.2 |
| 3 | 493 | 33.6 |
| 4 | 321 | 21.9 |
| 5 | 224 | 15.3 |
| 6 | 164 | 11.2 |
| 7 | 44 | 3.0 |
| 8 | 35 | 2.4 |
| 9 | 4 | 0.3 |

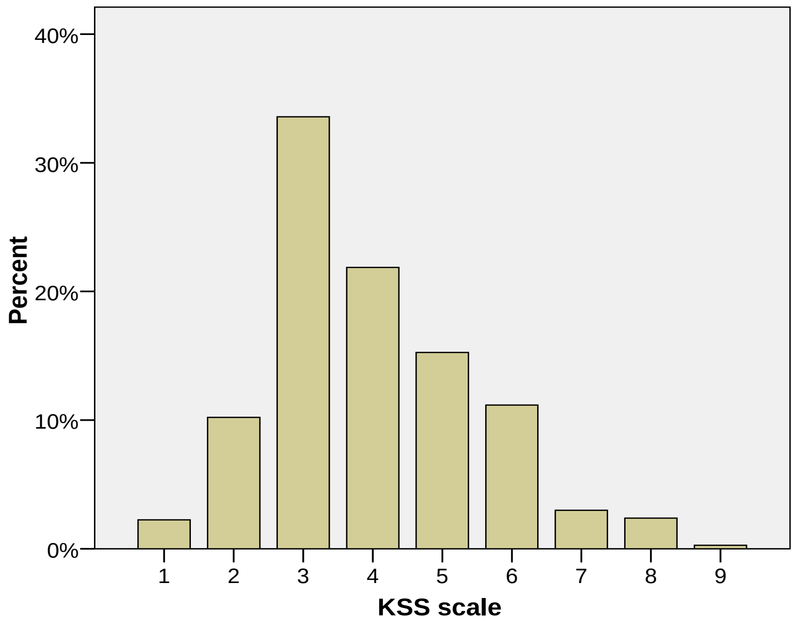


*Figure 21 KSS scale distribution plot (percentage on total for each score).*

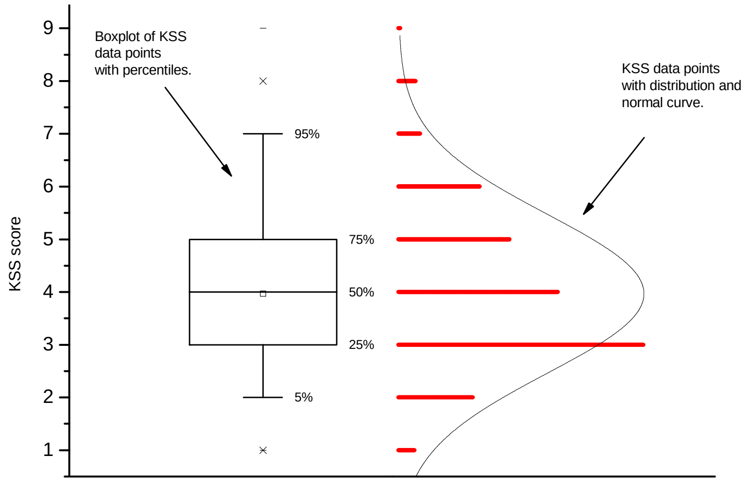


*Figure 22 Box plot and distribution of KSS data. The boxplot shows where 50% of the scores are (the box itself from 25% to 75%) and where 90% of the scores are (from 5% to 95%), median value is shown as a small square in the box. The number of scorings for each KSS value are shown as red bars on the right, where the normal distribution is plotted as well.*

### 6.1.4 KSS score and number of hours worked on each shift

Each working shift was supposed to last 4 hours for the participants in shift system 4x8 and 6 hours for participants in shift system 6x6. The actual number of hours worked differed sometimes from these numbers. Figure 23 shows that most participants in the 4x8 shift system worked 4 hours and in the 6x6 shift system, 6 hours, but also that there were participants who work for longer periods than intended in the watch system.

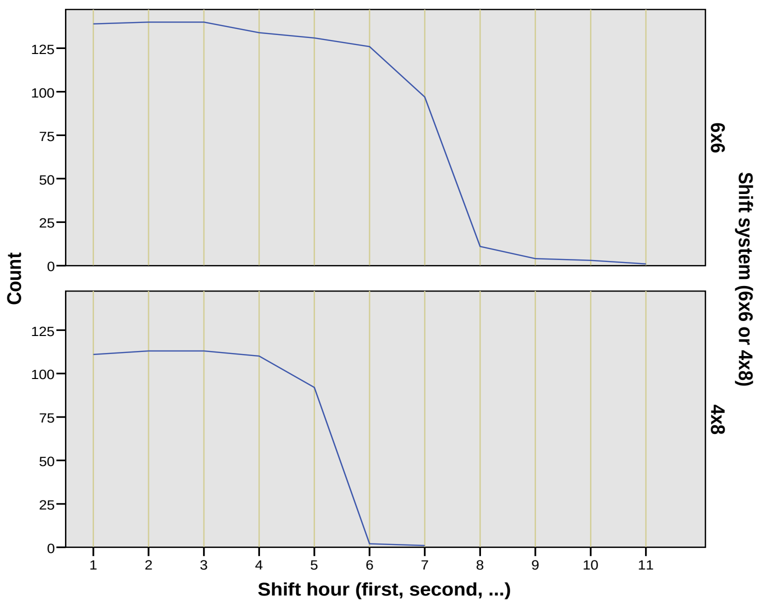


*Figure 23 Amount of KSS data scored for each shift hour worked. This plot shows how many hours the participants worked in each shift, since KSS data only for hours on duty is plotted. The firs number "1" on the x-axis stands for KSS data scored at the beginning of the firs working hour, and the number "2" stands for KSS scored at end of the first and beginning of the second hour, etc. Note that the plot shows actually discrete values, but has the form of a line, which simply interpolates the points.*

The KSS scores were investigated in relation to the number of hours worked in one shift. First, for the shift system 6x6 only the first 6 hours were included, and for the shift system 4x8 only the first 4 hours. Figure 24 shows the mean KSS scores for each shift hour. “1” on the x-axis stands for the first shift hour, the last number (“5” for the 4x8 system, and “7” for the 6x6 system) represents the KSS score at the end of the last working hour, thus 4 hours of work have 5 KSS scores. It can be seen that the mean KSS scores increased somewhat during shift hours, as would be expected. However the increase is not large, as the KSS values are under KSS score “6” (when fatigue starts). A tendency towards higher KSS scores in the 6x6 system is evident, especially at the end of shift system 6x6.

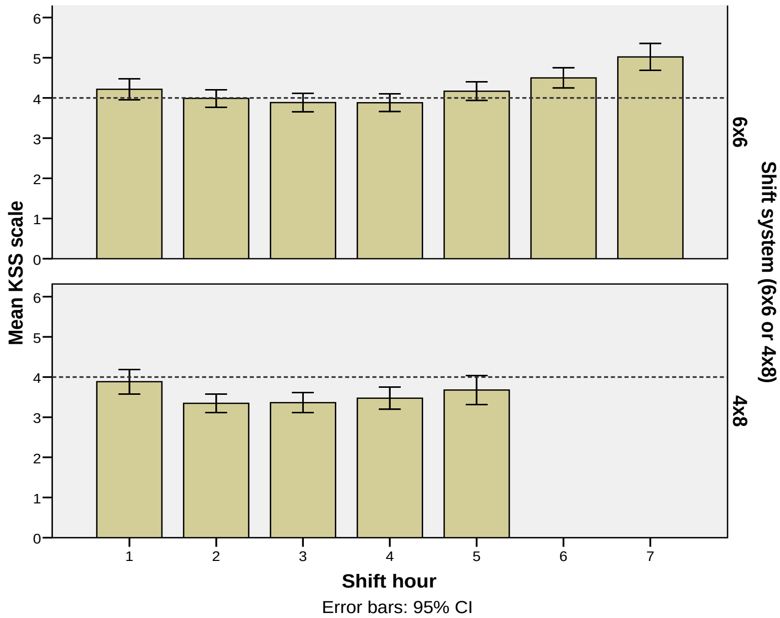


*Figure 24 Mean KSS score in relation to the hour worked in each shift. The first bar shows the mean KSS score when the shift was started, the last bar in each plot is the mean KSS score at the end of the complete work shift. 95% confidence interval for mean value is shown as error bar.*

Looking only at the KSS scores over 5, we see that these higher scores were registered more frequently as the working time exceeded the normal shift. The plot in Figure 25 shows that the highest percentage of KSS scores over 5 were scored during “overtime”, thus when the participants worked longer than the planned shift. The last working hour for both shift systems had only KSS scores over 5. This shows how time on shift affects sleepiness. Note that for the 6x6 shift system the first 7 bars on the x-axis represent normal working time, and for the 4x8 shift system the first 5 bars.

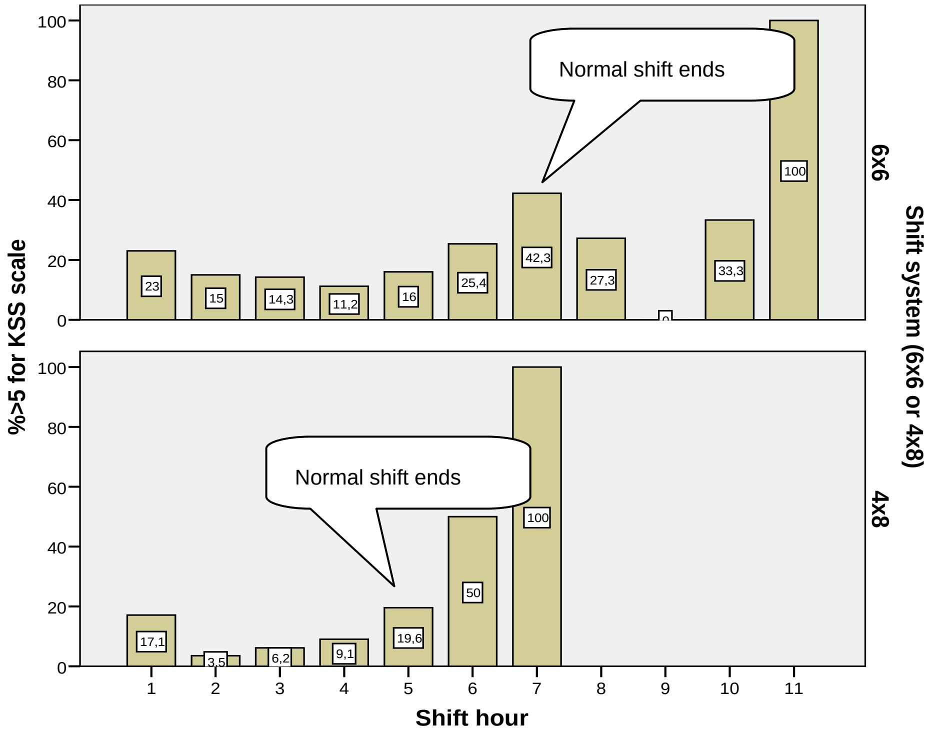


*Figure 25 Percentage of KSS scores over 5 plotted over each working hour. It can be seen that the highest KSS scores were during "overtime". For both shift systems the KSS scores registered during the last working hour (9$^{th}$ hour in the 6x6, 6$^{th}$ hour on 4x8) were 100% over the value of 5.*

Another factor of interest is comparing the sleepiness during night-time work against the sleepiness during daytime work. To analyse this all participants were coded by working time from between midnight to 6 AM, respectively from 6 AM to 12 AM. The analysis showed that both the shift system ($F(1)=11.82$, $p<.05$) and the time when worked ($F(1)=27.04$, $p<.05$) had an effect on the KSS score, and furthermore an interaction effect between both was found ($F(1)=31.01$, $p<.05$). The estimated marginal means for KSS score during midnight to 6 AM was 4.46 (standard error=0.074) and for 6 AM to 12 AM 3.99 (standard error=0.079). When looking more closely at the factor night-time against daytime it can be seen that during the night the KSS scores differed far more between 6x6 and 4x8 than during the day, as the 6x6 group was more affected by daytime than night-time work. Figure 26 shows this relationship: for the 6x6 shift system night-time work caused higher KSS score variation than for the 4x8 shift system.

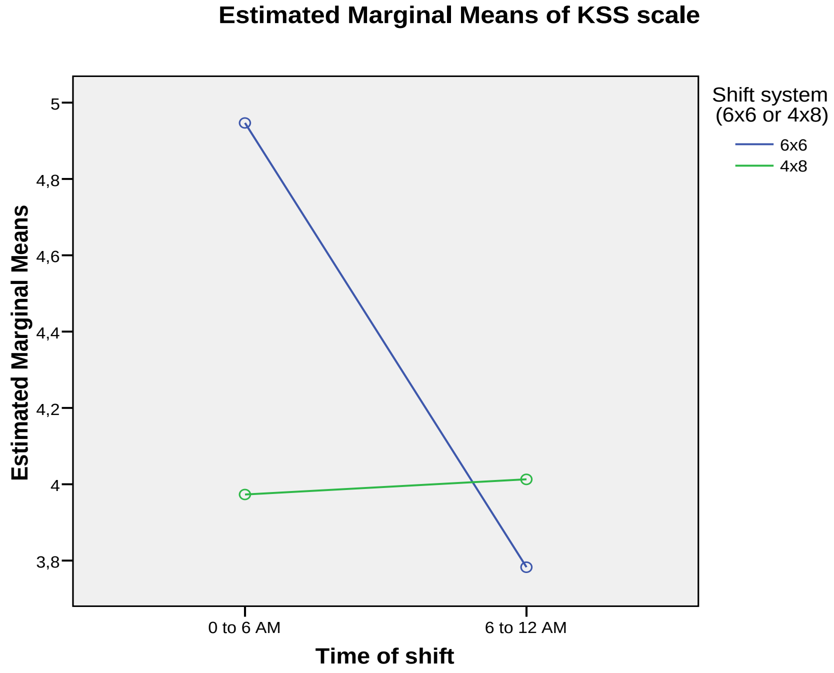


*Figure 26 Mean KSS scores for both shift system during daytime work and night-time work.*

### 6.1.5 KSS and shift system

A main hypothesis of the study was that the 6x6 shift systems would induce more fatigue in the participants, i.e. that the 6x6 system causes higher fatigue. KSS mean scores for each participant were calculated. Although the new mean value for all KSS scores of each participant is normally distributed, the original KSS score was not normally distributed, thus non-parametric tests are used.

A Mann-Whitney test shows no relationship between shift system (6x6 or 4x8) and KSS mean value. There is a tendency that the 6x6 system leads to higher KSS mean values, as Table 6 shows. The same approach was tested on the percentage of KSS scores over 5, 6 and 7 respectively, again for the shift system factor: no statistical significant difference was found, but always a trend to higher values in the 6x6 system. The data analysed includes hours worked outside the normal watch.

*Table 6 KSS mean values for both shift systems.*

| Shift system | Mean KSS | Std. Deviation |
|---|---|---|
| 6x6 | 4.037 | 0.80 |
| 4x8 | 3.498 | 1.05 |

Since we are mainly interested in finding differences for the higher KSS scores (when the participants are more tired) between shift system 6x6 and 4x8, the percentage of KSS scores higher than 5 for all participants was calculated. By doing this the factor “amount of observations per participant” is bypassed. The following boxplot (Figure 27) shows the percentage of KSS scores higher than 5 for the two shift systems. Although the 6x6 shift system shows a tendency for higher KSS >5 percentage, a Mann-Whitney test shows no statistical significant difference. The reason can be the large spread in KSS scores.

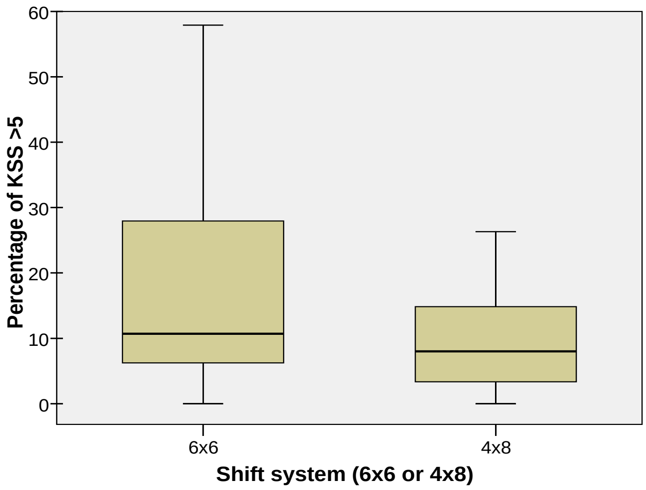


*Figure 27  Boxplot percentage of KSS >5 for the 2 shift systems. A boxplot shows the minimum, first quartile, median value, third quartile, and maximum of the data.*

The last working hour for each shift system was analyzed in relation to KSS score (this means after the fourth hour in the 4x8 and after the sixth hour in the 6x6 system). The mean KSS score after the fourth hour of work in the 4x8 shift system was 3.67 (±1.67), while in shift system 6x6 after the sixth hour it was 5.02 (±1.74). The result is statistically significant according to a Mann-Whitney U test (Z=-5.065, p<.05). This means that participants were more fatigued at the end of shift system 6x6 than at the end of shift system 4x8.

Looking at shift system 4x8, 6x6 and 6x6+1 separately, the relationships are similar, as seen in Figure 28. An analysis of variance showed no significant difference, although a trend is visible. The pure 6x6 system had slightly higher values than the other two.

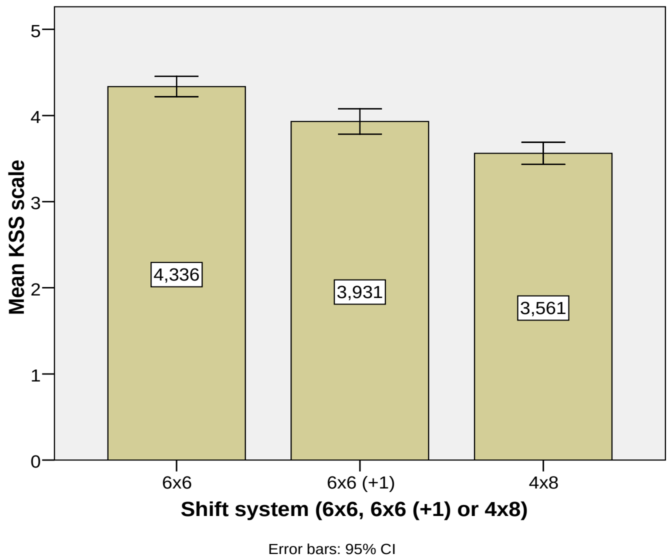


*Figure 28  Mean KSS scores for each shift system, here shift system 6x6 and 6x6+1 are separated. The calculated mean KSS score is noted in each bar, 95% confidence intervals are shown on the bars.*

### 6.1.6 KSS and time of day

It is assumed that time of day has influence on the KSS scores, i.e. night time work leads to higher mean KSS scores than daytime. This was confirmed in the analyses above. The bar graphs in Figure 29 show the result: the highest mean KSS scores were recorded in the late night and early morning hours. Analyzing the standardized (z-scores) KSS values, the fact is even easier to see (see Figure 30): night time hours induced higher tiredness than day time work (note: the z-score transformation standardizes variables to the same scale, producing new variables with a mean of 0 and a standard deviation of 1).

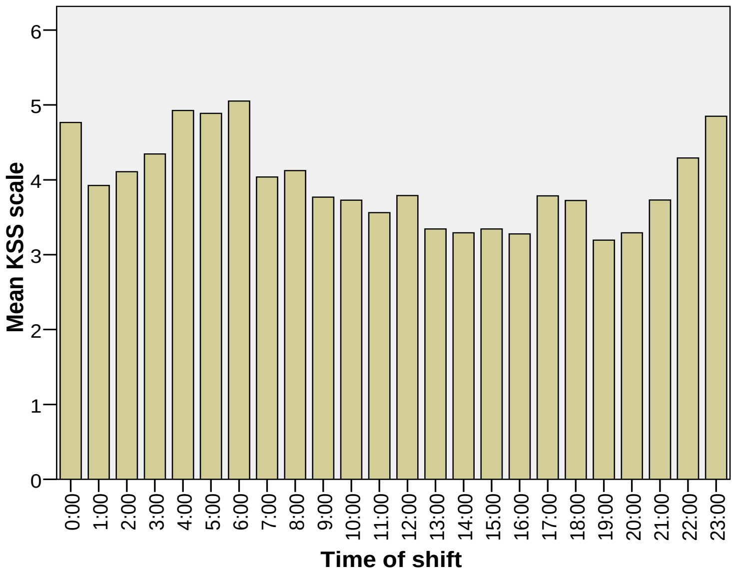


*Figure 29 Mean KSS scores and time of shift.*

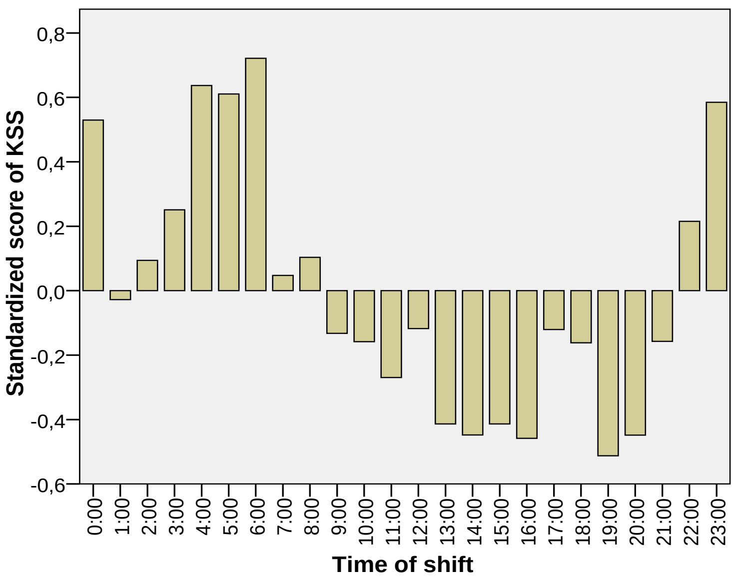


*Figure 30 Standardized KSS mean scores plotted by time of shift.*

Analyzing only the high KSS scores separately for shift system and time of day reveals again that the shift system 6x6 led to a larger amount of high KSS scores than the shift system 4x8. Figure 31 and Figure 31 show the percentage of KSS scores higher than 5 (when sleepiness begins) and respectively higher than 7 (when significant sleepiness with difficulty to stay awake is present) for both shift systems and time of day. The average percentage of KSS scores over 5 was 20.19 for the shift system 6x6 and 11.07 for the 4x8 system, the percentage of KSS scores over 7 was 3.46 for the shift system 6x6 and 1.29 for the 4x8 shift system.

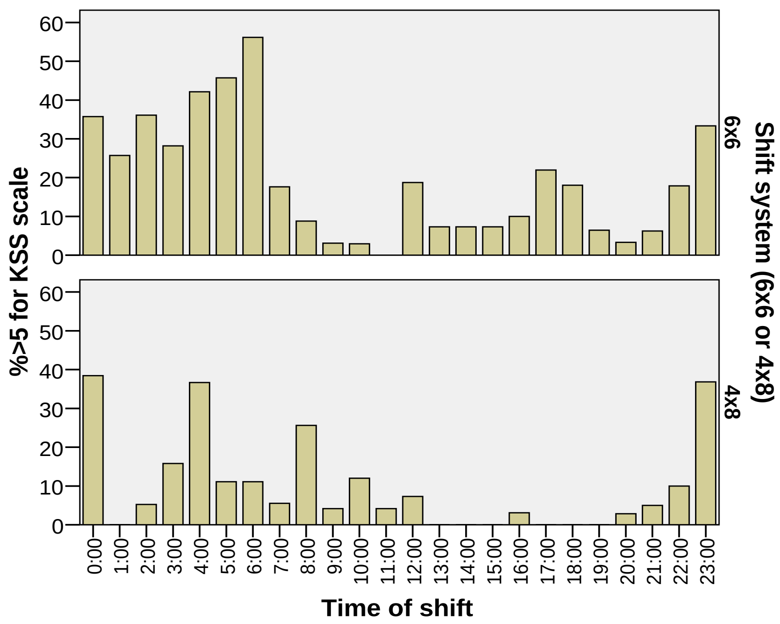


*Figure 31  Percentage of KSS over 5 for time of day and the two shift systems.*

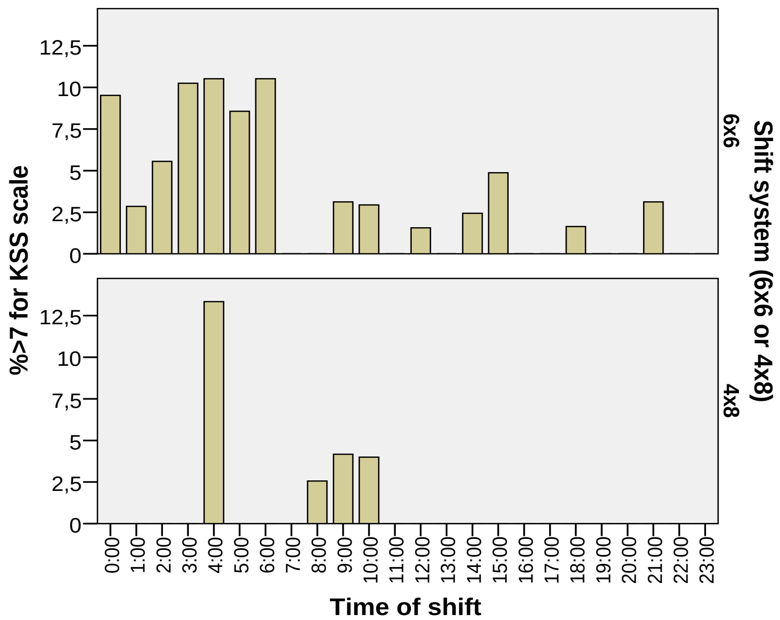


*Figure 32  Percentage of KSS over 7 for time of day and the two shift systems.*

### 6.1.7 Stress data

Stress scores were recorded together with KSS scores at each full work hour. The stress scores ranged from 1 (very low stress) to 9 (very high stress). The basic distribution of the variable is shown in Figure 33. It can be noted that in general the stress scores were low. The 6x6 shift system had a mean stress score of 3.23 (±1.38), while the 4x8 shift system had a mean score of 2.84 (±1.3).

We note that the stress score distribution during the time of day was somewhat different from the KSS score distribution. In Figure 34 the distributions of KSS and stress scores during time of day, normalised data, is shown together. There is a positive correlation between stress scores and KSS scores (Spearman's rho=.484, $p<.05$). The effect of shift system on the stress scores was analyzed: a GLM showed no significant effect of shift system, but there was a significant interaction with shift number (the more shifts the higher the stress scores, GLM Univariate: $F=60.254$, $p<.05$). This is similar to the findings for KSS scores and shift number.

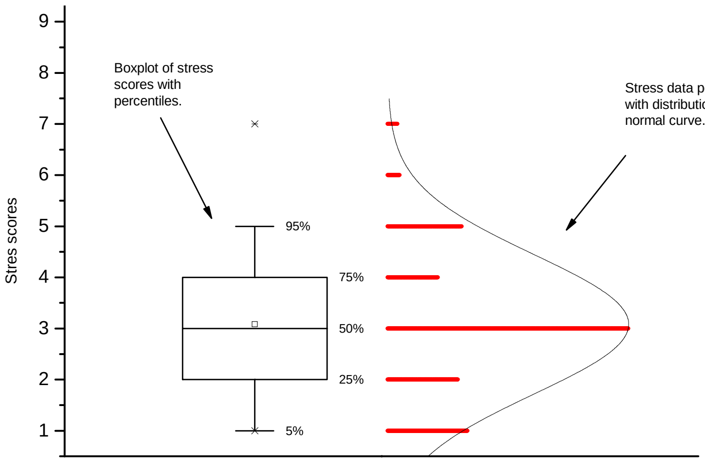


*Figure 33 Distribution of the stress scores with normal line and boxplot.*

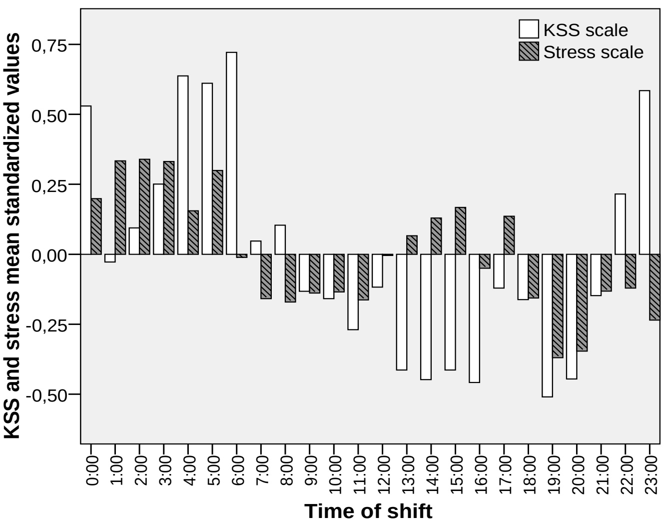


*Figure 34 Comparison of standardised scores of stress (striped bars) and KSS ratings (white bars).*

### 6.1.8 KSS and EOG mean blink duration data

A hypothesis was that the mean EOG blink duration was positively correlated with KSS scores. A line plot is created for each participant, for each time of the day. KSS scores and mean blink duration are transformed into relative Z-scores to allow comparison. In Figure 35 KSS scores are in blue colour, mean blink duration is green. Only 2 shifts per participant are plotted, in order not to mix 2 shifts with same time of the day together. From the plots below a direct connection between EOG mean blink duration and KSS scores is visible in a few participants, but not in all.

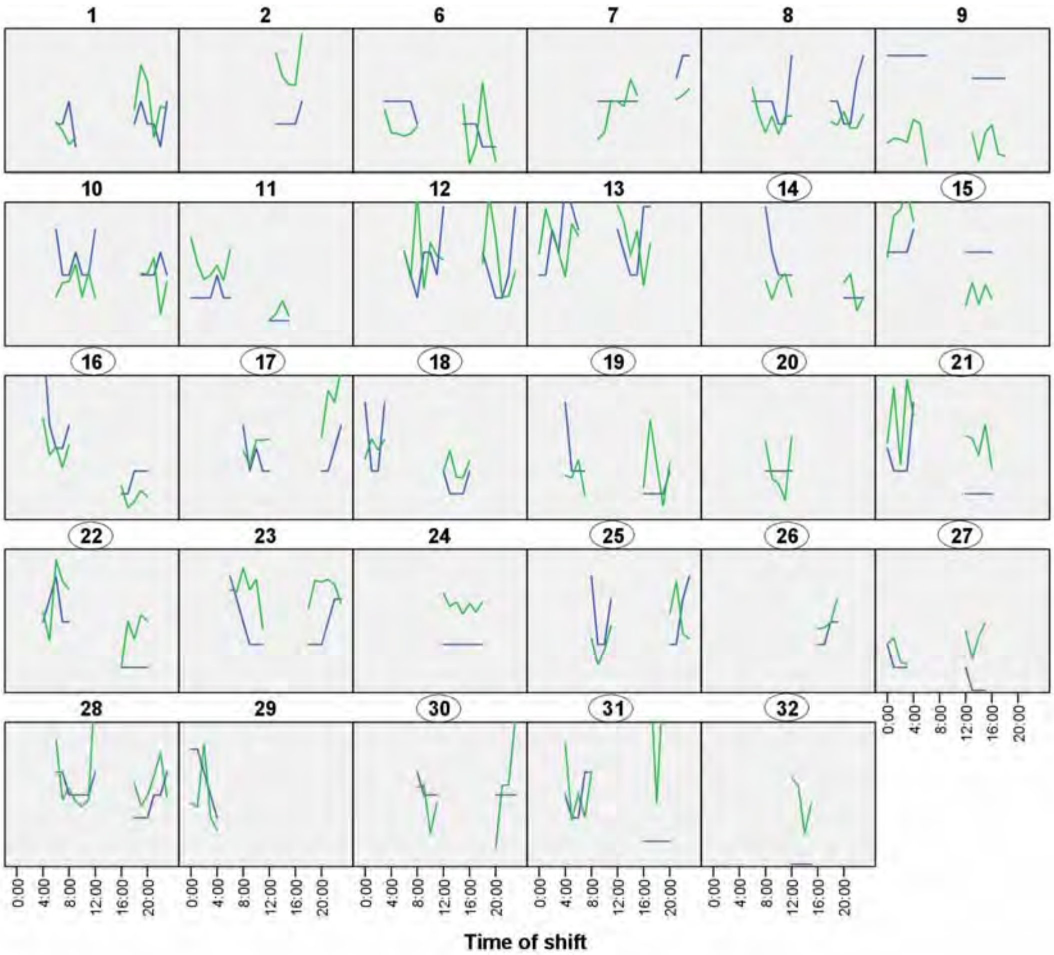


*Figure 35 Standardized values of KSS score and mean blink duration for all participants. Y-axis is relative value of the scores, x-axis is time of day. KSS in blue colour, mean blink duration in green colour. Each box is an example from one participant with valid data. 4–8 watches are circled.*

In a similar manner the KSS and mean blink duration standardized scores are plotted for two participants (one for each shift system, chosen randomly), in order to better analyse the similarities. The plots in Figure 36 and Figure 37 are two examples which show time of scoring on the x-axis, and KSS and mean blink duration on the y-axis. A correlation analysis on the whole dataset (all participants) showed only a weak correlation between the variables KSS score and mean blink duration (Spearman's rho=.137, p<.05).


*Figure 36  KSS and mean blink duration standardized scores for participant nr. 15 (4x8 shift system). KSS in green, mean blink duration in blue.*

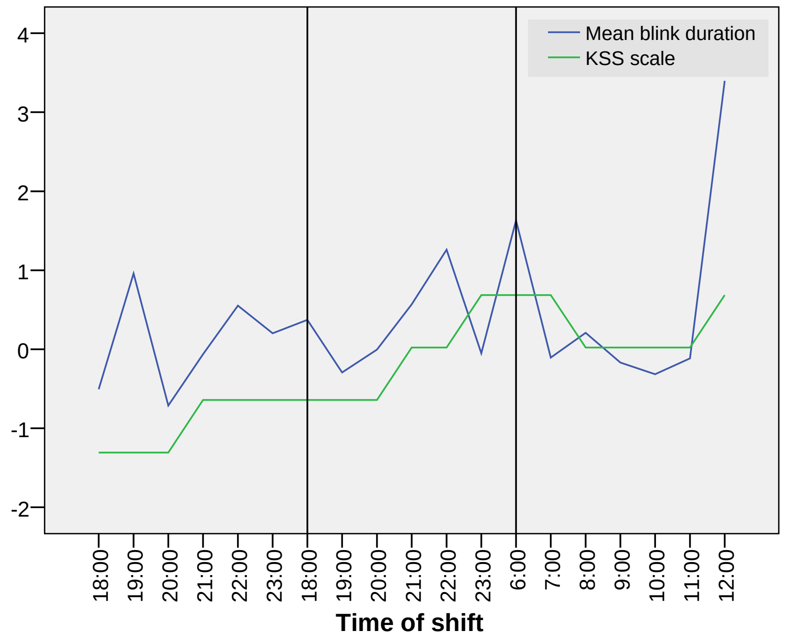


*Figure 37  KSS and mean blink duration standardized scores for participant nr. 28 (6x6 shift system). KSS in green, mean blink duration in blue.*

Following, the mean blink duration values are plotted for each KSS value over 5 for all participants (Figure 38). Here a clear tendency to higher mean blink durations for higher KSS scores is visible. However, the variance is large, which may be the reason that a non-parametric correlation analysis shows that there is only a weak positive relationship between KSS scores over 5 and mean blink duration (Spearman's rho =.273, p<.05). Plotting the mean blink duration for the shift systems separately and for all KSS values (Figure 39) shows the real picture: there is a large variance in the KSS scores, but a general tendency towards higher mean blink durations with higher KSS scores is visible when subjects are tired.

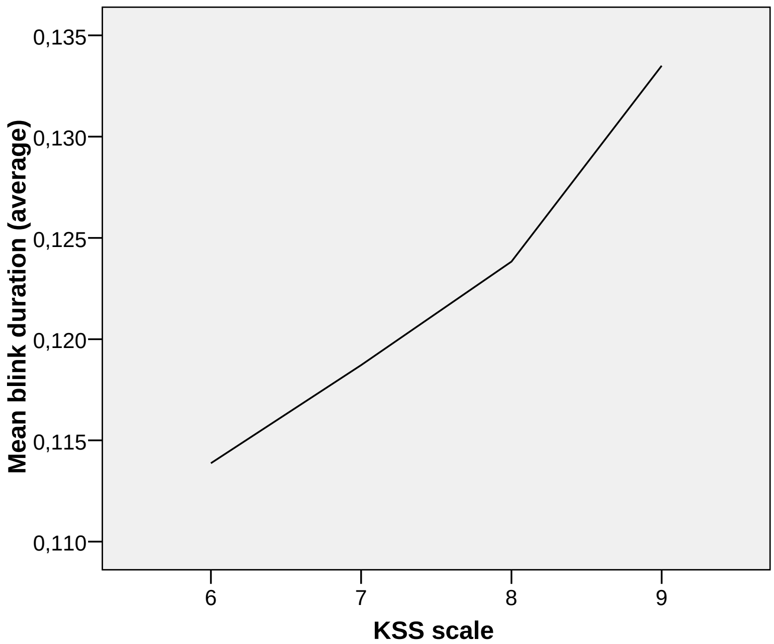


*Figure 38  Mean blink duration for KSS scores over 5.*

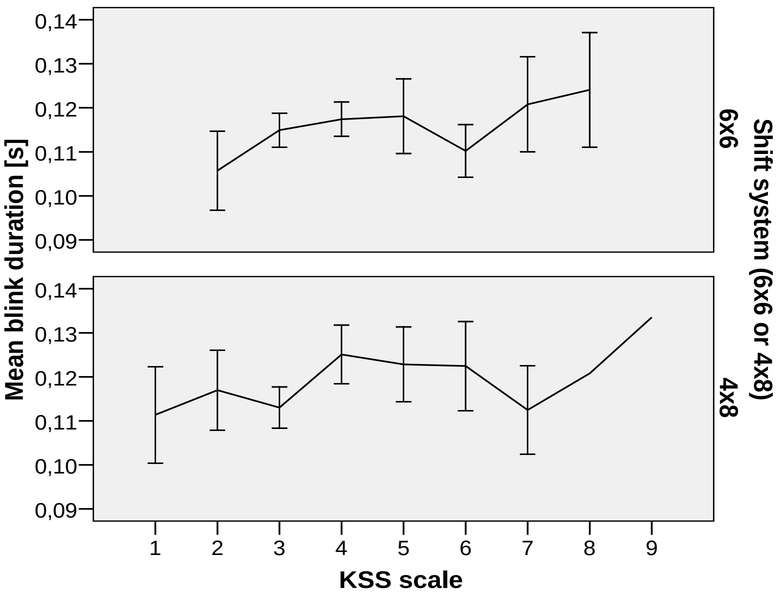


*Figure 39  Comparison of mean blink duration and KSS scores for both shift systems. The line shows the average values of EOG mean blink duration for each KSS score. Error bars show the 95% confidence interval for the data.*

### 6.1.9 Focus on extreme findings

The main focus of the “Fatigue at Sea” project was to discover relationships between sleepiness and shift system. With “extreme findings” we mean cases where participants displayed very high sleepiness. KSS values ranging over 6 (where sleepiness begins) are focussed on here.

**KSS scores**

From the KSS data scored during work time, the following was found:

- In 16.9% of the scorings the participants were tired (KSS 6 and upwards).
- In 83 occurrences the participants scored KSS 7 and above.
- 2.7% of the KSS scorings were “8” and “9” (difficult to stay awake). This means that during 39 occurrences the participants had difficulties in staying awake.
- Counting the frequency of KSS>7, shows that in 82% of the occurrences where very high KSS values were scored the participant worked in 6x6 shift system.

Figure 40 shows the percentage of occurrences where participants scored a high KSS score (>7) and if they were on the 6x6 or 4x8 shift system. Please note that the different number of available observations is not accounted for here. In order to account for the different number of observations in each shift system the percentage of KSS scorings over 5, 6 and 7 was analyzed for each participant and shift system: Figure 41 shows that in general more KSS scores of 5, 6 and 7 respectively were counted for participants in shift system 6x6.

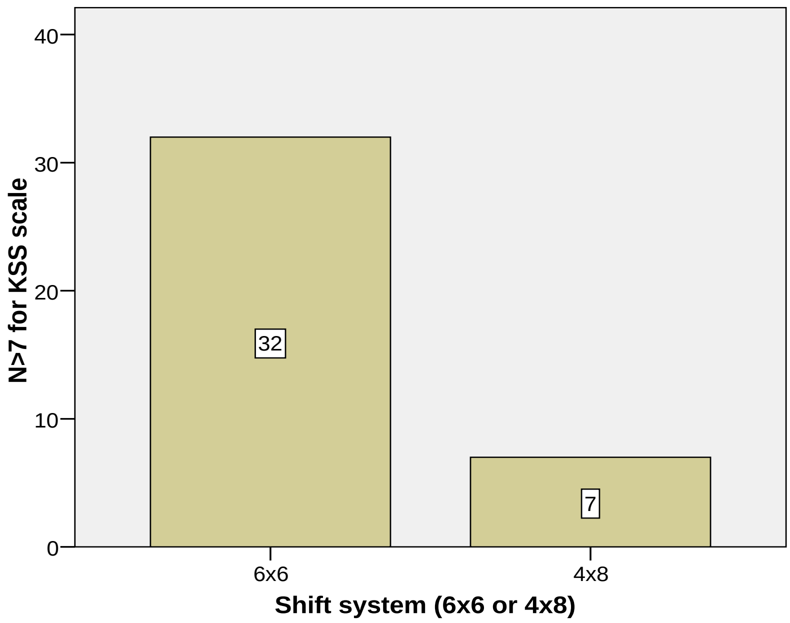


*Figure 40 Percentage of KSS scorings over 7 for the two shift systems.*

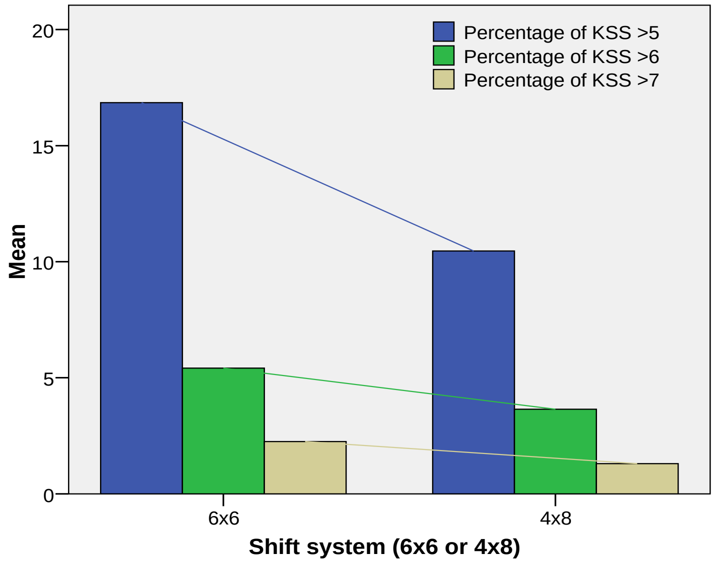


*Figure 41  Average percentage of KSS scores over 5, 6, and 7 on all scores for each shift system.*

### High stress scores and shift system

A similar analysis as for the KSS scores was performed on the stress scores. The maximum stress score recorded by the participants was 7 (on a 1–9 scale). The shift system 6x6 had many more high stress scores (score 6 and 7) than the shift system 4x8. In fact three occurrence of stress = 7 was scored by the 4x8 group (0.6 percent of all stress scores in this group), but 24 in the 6x6 group (2.6% of all stress scores in this group). Since the number of observations was different for the two shift systems, the percentage of stress scores over 5 on the total amount of stress scores in each group was analyzed, see Figure 42. Although a trend towards higher stress scores for the 6x6 shift system was evident, analysis of variance on the mean stress scores with shift system as between factor gave no statistically significant results, meaning that the difference in stress scores between shift system 6x6 and 4x8 can be unsystematic.

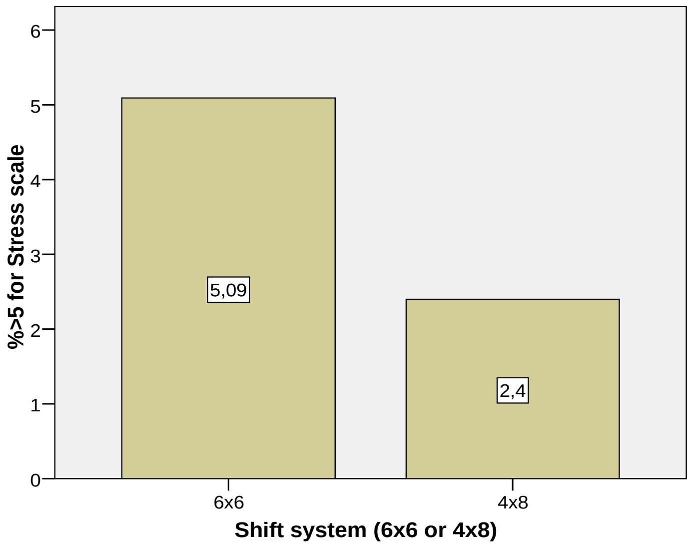


*Figure 42  Percentage of stress scores over 5 for the 2 shift systems.*

### 6.1.10 Reaction time test

Data was available for 24 participants after night shift and 23 participants after day shift. For 3 participants only the tests after the night shift were available, and for two other participants only the test results after day shift.

Already when starting to look at the data a major difference was evident: the reaction times for participants after the night shift had much higher variance than the times after a day shift, Figure 43 and Figure 44 show the results of the reaction time test for all participants. Each participant is one line; the average of all participants is shown as a thick red line. Figure 43 shows the result after the night shift: here the scorings have high variance and several scorings with long reaction times are present. Figure 44 shows the results after the day shift (scale on x- and y-axis is the same for both graphs), variance is lower here and fewer data points with long reaction times are found. When looking at the mean values and standard deviation this is confirmed. The mean value for the test after night shift was 0.35 seconds (±0.124) and for the tests after day time shift 0.306 seconds (±0.06). The difference is statistically significant (Z=-3.25, p<0.5). Non-parametric tests were used to account for the data distribution.

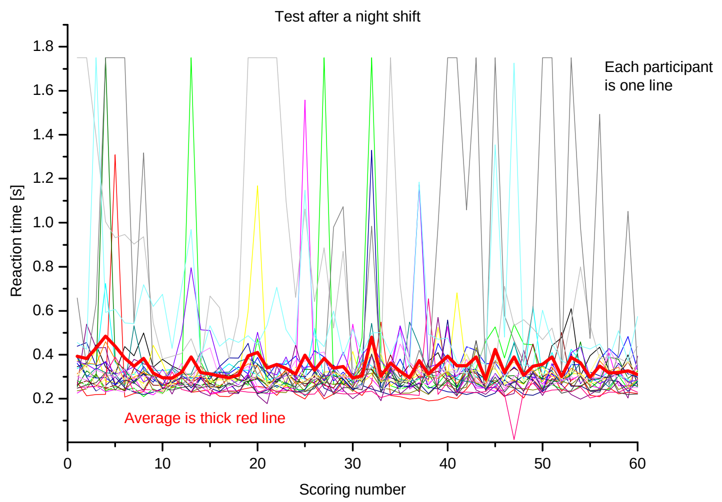


*Figure 43 Reaction time test for all participants after the night shift.*

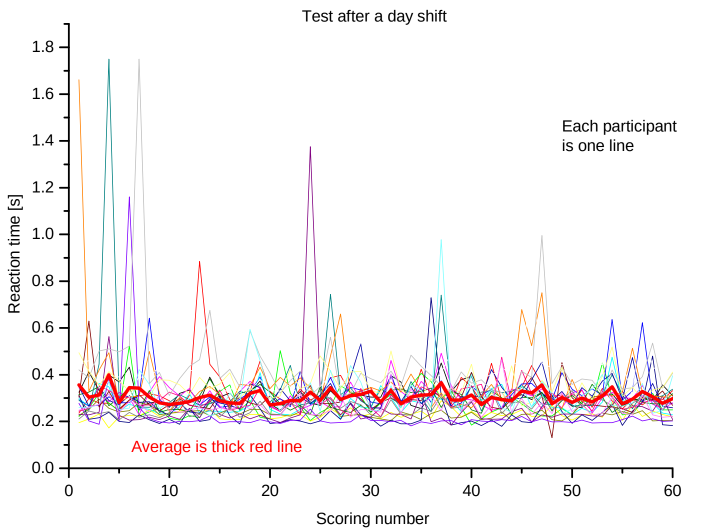


*Figure 44 Reaction time test for all participants after the day shift.*

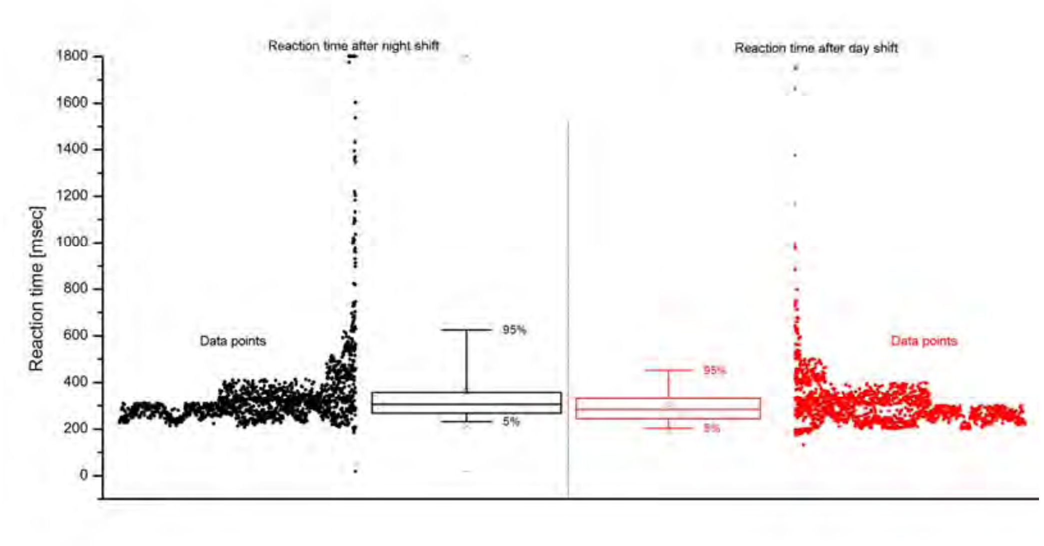


*Figure 45  Box plots of reaction time data after night and day shift.*

Figure 45 shows box plots of the reaction time data after the night shift (left in black) and after the day shift (right in red). The box plots display the 5–95 percentiles, as well as mean values and 50% box. Data points are plotted beneath the boxes to see the real distribution. In order to analyze the data more in depth, a hierarchical linear model (mixed linear model) was used: the procedure is similar to a repeated general linear model, but with advantages when it comes to missing values as was the case in our study. The goal was to study the effect of other factors such as shift system (6x6 or 4x8) on the reaction time data. The mixed linear model confirmed the results above, as the effect of night versus day shift was significant on the reaction time values ($t=5.6$, $p<.05$). No effect of shift system was found for the reaction time values, and a tendency to higher values for the 6x6 shift system. Thus it can be said that participants scored higher reaction times after a night shift than after a day time shift, and that shift system did not affect reaction times significantly.

### 6.1.11 Influence of nationality of participants

Analysis of variance on the mean KSS score for each participant shows that participants from the Philippines had a tendency to report far lower KSS scores than their Swedish colleagues ($F(1)=27.18$, $p<.05$). The average KSS score for the Swedish participants was 4.13 (±0.69) and for the Filipino 2.56 (±0.68). Considering that these are mean values on all reported KSS scores the difference is considerable. Data related to KSS scores such as percentage of KSS over 5 is also well affected here. The reaction time after day shift and after night shift (which is analyzed in detail in section 5.1.12) was also affected by nationality (after night shift: $F(1)=5.46$, $p<.05$), after day shift: $F(1)=10.34$, $p<.05$). Although the difference was only 0.045 seconds in total, Table 7 shows the systematic differences, which were confirmed by the analysis of variance.

*Table 7 Average RT in msec for participants divided by nationality.*

| | | Nationality | | |
|---|---|---|---|---|
| | | Filipino | Swedish | Total |
| Average RT after day shift | Mean | 369.48 | 288.17 | 305.85 |
| | Minimum | 315.79 | 224.15 | 224.15 |
| | Maximum | 452.13 | 434.04 | 452.13 |
| | N | 5 | 18 | 23 |
| Average RT after night shift | Mean | 456.01 | 322.48 | 350.30 |
| | Minimum | 321.69 | 245.23 | 245.23 |
| | Maximum | 699.34 | 702.16 | 702.16 |
| | N | 5 | 19 | 24 |

## 6.2 Actiwatch results

The actiwatch results show that participants seem to sleep for 8 hours totally in the 6x6 system and 7 hours in the 4x8 system, see Table 8. However, after analysis, and removing of awake or restless periods, we see that their actual sleep time is more than an hour less in both instances, see Table 9. The 6x6 watch seems to sleep more, but this is in most cases separated into two sleep periods. The sleep efficiency is low in both watch systems, around 75%, see Table 10.

*Table 8 Assumed Sleep time (hh:mm).*

| | Mean | STD | N | 95% CI |
|---|---|---|---|---|
| 6h | 08:02 | 01:36 | 36 | 00:10 |
| 4h | 07:05 | 01:47 | 42 | 00:11 |

*Table 9 Actual Sleep time (hh:mm).*

| | Mean | STD | N | 95% CI |
|---|---|---|---|---|
| 6h | 06:42 | 01:26 | 36 | 00:09 |
| 4h | 05:58 | 01:39 | 42 | 00:10 |

*Table 10 Sleep Efficiency (%).*

| | Mean | STD | N | 95% CI |
|---|---|---|---|---|
| 6h | 76.5 | 11.21 | 54 | 1.03 |
| 4h | 74.3 | 9.06 | 53 | 0.84 |

## 6.3 Interviews

Below, the questions asked are presented in bold followed by a summary of the individual answers. The answers are grouped, but not presented in any particular order that might map them to a certain company. The answers are not discussed here. What is presented is only the view of the companies.

**How many employees on board on your ships have tasks that might be sensitive to fatigue/sleepiness?**

About half of the companies answered that all crew members have tasks that might be sensitive to fatigue, and gave numbers ranging from 2 to 50 persons per ship, depending on type of ship. All thirteen companies agreed that officers on the bridge always had tasks that were sensitive to fatigue.

**Is this a problem? If yes, for whom.**

No company experienced fatigue as a problem during normal conditions. One of the companies answered that they use the three-watch system which gives the crew time to relax and to sleep. Another of the companies says that the debate may have made the fatigue problem larger than it is in reality. Fatigue problems may occur onboard Roro ships that enter and leave port at any time, day or night, especially for crew members who were on duty during the night and have their ordinary watch the day after. Also when the vessel is loading or discharging, fatigue can be a safety problem. Especially mentioned was when the ship has to travel where there is ice. Fatigue can be related to age; one comment was that older people get tired more often than younger. If one of the crew members is tired it will have an influence on the whole crew and therefore on maritime safety. Younger people with small children are used to stay awake for longer periods and to sleep in shorter periods. Officers' jobs have become more technical, with longer hours and more responsibilities for more and more complicated equipment and there is more paper work and inspections etc. At the same time, crews have gotten smaller and the routes are shorter and the schedules are tighter. The laws which regulate the time for rest and sleep do not always work due to these reasons.

One of the companies, which has crew members from different countries, said that the foreign crew members have to work longer periods on board than the Swedes. The Swedes try to help the foreign crewmembers to get more rest by working during free hours.

Fatigue is often one cause (of several) of accidents and after an accident insurance companies are interested in the crews' sleeping periods, and fatigue levels. Fatigue is also a company problem, because it is a question about the working environment and the company can change the working situation onboard for the crew, for example more personnel onboard or a silent sleeping place.

One comment was that "In "the good old days" a man was a real man if he didn't sleep much! Time has changed this a lot but on some ships it is still the truth."

**Do you take actions to decrease this problem?**

One company says that they have changed the environment onboard so that the crew will not be disturbed during their resting/sleeping hours. Another company says that they have changed the watch system. A shorter watch when the weather is bad is another solution. All of the companies are aware of the fatigue problem, but some of them do not believe it is a large problem.

**Do you have systems on board or on the bridge that may be sensitive to interference by electronic equipment? If so, what kind of systems/equipment?**

There is a lot of technical equipment onboard already so the majority of companies do not think it would cause any problems. However, many point out that this must be checked and monitored to be on the safe side. DP-systems onboard offshore ships could be sensitive to disturbances; before any new equipment is integrated it should be tested. An example given was that on some ships you are not allowed to use mobile phones on the bridge today, but this is because of the ability to concentrate more than a technical disturbance problem.

**If available, would you consider it worthwhile to ask employees to carry fatigue monitors to increase safety and wellbeing? Please give reasons for yes or no.**

Five answered yes and five no, but only for research matters. One company answered yes but could not find any need for such equipment today, and said that if a problem occurs then that would be the time to act. One of the companies answered no because they do not see fatigue as a problem. One answered maybe, but only if they can see any maritime safety reasons.

One company said that it would be interesting to make a test with fatigue monitoring during the ordinary watch and then change the watch hours and make a new test to see if there were any differences due to fatigue. It is important to test and see if there are effects on fatigue and if the crew itself experiences any difference. We naturally take note of this willingness to participate in research.

Many ships have a warning system where the crew has to reset the system every 30 minutes or so. Two of the companies answered that this system is very disturbing for the crew on duty. A better system would be one which was only initiated when the person is tired.

Another comment was that the equipment should fit the whole crew and should not be personal equipment.

**Do you think it likely that monitoring devices would be accepted by the employees? If not, why?**

All the companies answered yes, but the equipment must be comfortable to wear and the crew has to know the reason why they should wear it. There could be differences between crew members, some persons might refuse to wear such equipment.

**If worthwhile, would you be willing to buy such equipment? If not, why?**

One of the companies answered no, because it could make the work on board difficult to perform, and who should tell a crew member that it is time to go to sleep, somebody would have to act as a "parent" which would not be good for the spirit onboard.

Seven of the companies answered yes and five answered maybe. Maritime safety matters were the most common cause for these answers and a good functionality was another.

**What might be an acceptable cost for such equipment per employee?**

Many companies could not give a sum of money for such equipment. It depended on whether only the bridge officer should have the equipment or the whole crew. It will be easier to answer when there is such equipment on the market. If the accidents decrease it could be worth to make an investment. Five companies gave a guess about the investment sum, which ranged from 5,000 to 25,000 SEK per crewmember and year or 100,000 SEK per ship.

**If using fatigue monitoring equipment would be connected to a, say, 30% reduction of insurance fees, would that make it interesting to use such equipment? If not, why?**

All companies answered yes! One company answered that the primary issue is the human being and safety, and a reduction of the insurance fee would be a bonus. Another company answered that if you compare to the cost of an accidents it will be OK. Hopefully the price of the equipment would not be higher than the reduction of the fee. Another says that the reduction does not have to be that high to make it interesting to buy the equipment.

Another comment was: what should one do if a person wearing such equipment seems to be too tired and causes an accident? It would be a legal matter.

# 7 Discussion

## 7.1 Method discussion

There are always things to improve and it is of great value to document what can be done better. This chapter is about possible methodological improvements for future field studies.

### 7.1.1 KSS and diaries

The instructions for the participants about which diaries to fill in and how often could be made clearer. If possible the participants should also have the opportunity to practice the self-rating scales. It can be difficult to start rating drowsiness and stress on scales one has not seen before. Calculating mean values on KSS and stress scores is questionable, as the variables are not strictly interval scaled; which should be considered here. However, as the KSS scale has been validated against EEG measurements, we judge it to be a valid procedure. Regarding the health questionnaires, 9 were not handed in. We may try to resend these to the participants to complete the data set.

### 7.1.2 Participation

An earlier contact with possible participants would make it possible to decide whether they really want to participate or if they do it because they feel that they have to. Even though all was done to ensure participants understood that participation was voluntary, there were a few cases when the test leader had the feeling that the participant was not comfortable with the experiment. When several crew members are asked to participate, it can be hard for one to say no if the others say yes.

### 7.1.3 EOG

The equipment for measuring EOG is a bit heavy to carry around. Normally it is used by VTI in a car simulator and the box is then placed on the roof of the car. The participants now had to carry the equipment on a belt which was a bit uncomfortable when walking around on the bridge for several hours. One could look at possible alternatives for carrying the equipment or consider lighter variants.

### 7.1.4 Reaction time test

We considered making a more ecological test, relevant to the task and performable on the watch. One idea was hand steering and measuring for instance course keeping. This idea was discarded due to the possibility of interfering with watch duties and possible bias of varying weather conditions. The length of the reaction time test can be discussed. Those advocating a long test (e.g., 10 minutes) argue that drowsiness does not show until after a few minutes (Lisper & Kjellberg, 1972). On the bridge it is often stressful and annoying for the participants to focus on the test for six minutes and there is a risk that we will only see effects of how stressed they were at the moment or how well they can shut out other incoming information. As mentioned, we chose to make it 6 minutes (Axelsson et al., 1998). However, the mean reaction time value did not differ much in the last 2 minutes of the test. It is unclear how learning effects and increased loss of concentration in addition to fatigue affect the reaction time, but from our results a test length of 4 minutes or less (against the 6 minutes used) would have been sufficient to give the same results. When looking at the reaction time development over a complete test for a single participant, it seems as if the first 5 to 10 scorings could probably be excluded from the analysis, as they seem to indicate a learning curve.

### 7.1.5 Experimental design, data quality

The original purpose of measuring twice or more on the same ship was largely abandoned due to logistical difficulties. The experimental design was repeated measures with between subject factors (different shift system between participants). The structure of the collected data, together with the high amount of missing data for EOG data and for KSS data, makes the data analysis challenging and possibly limited. It should be said that the database is not "ideal" to extract statistical conclusions about the research hypotheses. The low number of occurrences on the total number of observations makes statistical inference difficult.

### 7.1.6 Interviews

The interviews were performed at the end of the project, during the spring of 2007. This may have had an impact on the answers. Since it is possible that some companies have participated in the field study, they may have a preconception of what fatigue measuring equipment could look like from having seen the scientific measuring equipment. If we had performed the interviews in the beginning and end of the project we may have been able to discern effects of knowledge dissemination.

## 7.2 Results field study discussion

### 7.2.1 KSS

The Karolinska sleepiness scale was used as a subjective self-scored measure of sleepiness. "Normal" shift times as well as periods where participants worked longer than the planned 4 or 6 shift hours were analyzed if KSS ratings were available. Working hours after the normal shift can mean participants are still on the bridge working as a watch-keeper, for some reason leaving the normal shift system. This can happen for example in preparation for a long journey in the archipelago or for arrival to port. They may also be performing work "off watch" on the bridge or elsewhere on the ship.

KSS ratings ranged from 1 to 9, with a median value of 4 and the most often scored value being 3. The sleepiness ratings were generally low. We have reason to believe that participants have rated their own sleepiness a bit carefully. Some have expressed worries about being in a study and feeling observed. The mean value of how much sleep the participants think they need is lower for the two-watch system than for the three-watch system. This can perhaps be explained by that the two-watch mates are used to sleeping less and do not remember what it feels like to be totally rested. We have heard comments like: *"After a few days at home I know what alert is"*. *"I did not know how tired I was until I changed from two-watch to three-watch"* or *"It was worth the lower pay"*.

As will be discussed later, the way of scoring KSS values by the participants cannot be considered totally reliable, as factors such as nationality may play a role. Therefore it would have been interesting to have an expert scoring of the sleepiness, by observing external signs of sleepiness. As this was not possible in the study for practical reasons, it can only be speculated if the participants underscored their sleepiness. We also speculate that if an underlying, latent sleep need existed in an individual, it may be more difficult to judge one's own level of sleepiness. Although we have no scientific support for this, it is a known fact that cognitive functioning is degraded by sleepiness – and therefore judgement may be impaired.

Another discussion point is the "general level of sleepiness". We know from personal experience and discussions with participants that a long trip on a ship is very demanding, and that people build up a latent sleepiness during the trip. This can lead to a state where participants are not recovering until after having been perhaps as much as one week at home resting. In other words it could be expected that the baseline for sleepiness is higher on board (even after a night's sleep) than when at home. This effect will be even more evident for long trips (for example 6 months), which is the case for ships under certain flags. It would be very interesting to analyse this "base level" of sleepiness at home and then after a number of weeks working on a ship.

We had expected greater differences between KSS values at home and on board and also between sleep quality and sleep length at home and on board. The reason for the small differences could possibly partly be explained by the suspicion of low ratings in general but also by the fact that the days ratings at home were given the first three days at home after a long on board period. We have reason to believe that this at home period is not entirely representative for the total home period. The reason why three days were chosen, was an assumption that during these three days, we would see recuperation. The number of days filled in at home varies for all participants and has not yet been fully analysed. A qualitative overview of changes over these days is planned for future work.

KSS scorings rose somewhat during a shift, meaning that the participants became more tired as the shift wore on. This behaviour was more distinct in the shift system 6x6, however, the increase is not large when looking at mean values. The last working hour during normal shift time (not overtime) led to significantly higher KSS scores in the 6x6 shift than in the 4x8 shift. The result can be trivial, as the participants in the 6x6 system had worked 2 hours more than the colleagues in the 4x8 system, but there is still the fact that their KSS scores were higher while they were manoeuvring the ship, which could constitute a risk. High KSS scores (over KSS=5) were present more often when the participants worked longer than the normal shift hours (overtime). This shows that overtime is demanding for them, and reduces the number of hours to rest and sleep before the next shift. The final working hours (including the overtime) led to KSS scores which were to 100% over 5. Night-time work was more fatiguing than day time work, and there was also an effect of shift system. It seems as well that the 6x6 shift workers are more affected by night time work than the 4x8 shift workers.

The high number of KSS scores at 6 a.m. seen in Figure 34, are both from the relieving and the relieved watch. The watch-change effect is also visible in figure 34 on the 4–8 watch ships, at 4 AM. The analysis showed a significant effect of the factor "sequential shift number" (the first, second, third, etc. shift during which the participants were measured), for KSS scores over 5 and over 6. This could perhaps be expected: with more shifts worked the participants get more tired. However, it is interesting to see this trend over as little as three days onboard.

Some possible reasons for this may be that participants are one or several of the following:

1. Learning to use the scale and getting better at judging their sleepiness. However, this usually only takes a short time, and the diaries were often started before EOG measurements.
2. Getting more honest (or conversely?).
3. Becoming more aware of their fatigue, perceiving more accurately how they feel.
4. Becoming more tired.

High KSS scores (over 6) were scored in almost 17% of the cases, and in almost 3% of the cases the participants had difficulty in staying awake (KSS 8 or 9). The shift system 6x6 led to more KSS scores over 7 than the shift system 4x8. In general high KSS scores were found more often in participants in the 6x6 shift system. The same is true for the stress scores, which were recorded in parallel to the KSS scores. Statistical analyses gave few conclusive results, one reason can be the high variance in the scorings. It is likely that a higher number of participants would have improved the results of the statistical analyses. However, from trends in the data (and the observations by the test leader on board of the ships) it seems evident that the 6x6 system is more demanding.

We observed different strategies for filling in diaries. Some were diligent and did it every hour, on the hour. Others might fill in afterwards, for a few hours, or for a whole watch. These different strategies may influence the scoring. How good is one at remembering how tired one has been? If one is unsure, is there a tendency to over- or underrate?

We also see a trend that the pure 6x6 has higher KSS scores than 6x6+1 which in turn is slightly higher than 4x8, which was to be expected. It could be suggested that we bias results by analysing these two groups of ships together, even though it is necessary for statistical reasons. The actual hours of work on watch should be very similar. It is the amount of work performed off-watch which may be less on the 6x6+1 ships, as there is a watch-free captain to assist with administrative work, or archipelago journeys and pilot waters for instance. The seafarers on the 6x6 ships may perhaps not spend more than 12 hours on the bridge but they almost certainly spend more time working. One seafarer says: “Most tiresome is when we are in port, then all have to work no matter what shift. When we have a few days at sea we can rest” [Mate in two-watch on Baltic sea]. Another says “84 hours of work every week, plus overtime!”

### 7.2.2 KSS and EOG

KSS and EOG mean blink duration were supposed to be both a measure of sleepiness, the first a subjective measure, the second an objective one. In consequence we expected a relationship between the two measures. This was confirmed by the analyses, but to a lower level than expected. When observing KSS scores in the higher range (over 5) this relationship is more evident, and the positive and significant correlation results prove this.

There are a number of factors which may have disturbed the possible relationship between KSS and EOG mean blink duration: The base level of tiredness may be different for our participants, and do they really have the same feeling of what being really tired is (in other words does for example KSS level 7 mean the same for all participants)? Are they already biased, by, perhaps underlying fatigue? As mentioned in another part of the discussion it can only be speculated about the real cause, but KSS scoring by an expert observing the participant could have given more reliable KSS values. VTI has seen this tendency in other studies. There may be a threshold, or an interval where self-scoring works and does not work. Has KSS been under-scored? (See Figure 46.)

It is unclear if KSS and EOG mean blink duration generally have a better correlation above a certain KSS level, but other psychophysiological measures speak in favour of this. For example it is known how EEG recordings show sleepiness levels above KSS 5 much more clearly than at very low sleepiness levels. As mentioned in the methods part of the study from this data the mean blink duration over ten-minute intervals was extracted and used as measure of sleepiness. The results were not as straightforward as expected, as the correlation between KSS and mean blink duration was present, but not high, and visible only for high KSS ratings. There can be different reasons for this. Firstly, KSS scorings can have been inaccurate, i.e. that participants did not score the sleepiness they really felt. We discuss later that Filipino participants may under-score their real sleepiness for different reasons, this may also be true for Swedes. Secondly, mean blink duration extraction algorithms may have been inaccurate or simply inappropriate. The performance of the algorithms was checked manually in terms of blink detection and given the basic nature of calculating mean values, a small number of very long or slow blinks (which denote high sleepiness) have little weight on the total mean blink duration.

Remember that only the mean blink duration value for the last ten minutes before the KSS scoring was recorded are used in the analysis, thus the remaining time is not considered. An example could be: a subject which almost falls asleep for 5 minutes half an hour before the KSS scoring and thus displayed long mean blink duration values will not be detected here. To overcome this problem it would be necessary to analyze all blink duration values without calculating mean values over a time period, maybe with time series analyses. Third, the mean blink duration may not be the appropriate measure to use as measure of sleepiness. The literature shows numerous studies which use blink duration for sleepiness detection, and many of the studies as well propose different measures, as for example eye closure speed, amplitude of EOG signal during blink divided by peak closing velocity, and the often cited PERCLOS measure. In a further study it would be worth investigating and comparing such variables.

Future analysis also includes to look at the participants on 06–12/18–24 and 00–06/12–18 watches, respectively. It can be assumed that those on the 12–6 watch are more tired and get less sleep, and sleep of a lower quality, since they are working when the biological rhythm tells the brain and body to sleep, and trying to sleep when the brain wants to be awake.

### 7.2.3 Stress scores

Stress scores were registered at each full hour, together with KSS scores. There is a positive correlation between KSS and stress scores. The maximal stress score recorded by the participants was 7. While in general stress scores were low, the shift system 6x6 had many more high stress scores (score 6 and 7) than the shift system 4x8. In fact three occurrence of stress =7 was scored by the 4x8 group, but 24 in the 6x6 group. For the lower stress scores no difference between 6x6 and 4x8 systems were found. There was a positive interaction between shift number and stress score, meaning that the longer the participants had been working on the ship, the higher the stress scores were. The stress scorings during time of day followed somewhat the KSS scorings (higher KSS and stress during night time), but showed a difference during day time: here stress rose after 12 AM until afternoon, and fell again in the early evening (see Figure 34 on page 51). The reason that stress and sleepiness correlate positively is not straightforward. Workload will play an important role here, as well as experience of the participants. It could be worth considering other “confusing variables” such as weather in general, visibility, experience of the participant, personal situation of the participant, as well as the traffic and navigational situation.

Also interesting to note is that we did capture the effect of stress suppressing fatigue, an example of which is shown in section 7.2.8. An important finding, since it has ramifications for safety. It would be easy to think one is alert during a period of high workload, when in fact it is due to the workload. The sleepiness is still present and will surface when the workload diminishes. We should in further analysis look closer at the data to see how many instances there are and to study to what extents workload can suppress high levels of sleepiness.

### 7.2.4 Reaction times

Reaction time was recorded after night shift and after day shift. The results of the data analysis on the reaction times were very clear, as the participants performing the test after night shift had longer reaction times. Scorings after the night shift had a high variance and several scorings with long reaction times are present. This kind of variance is typically seen when testing after alcohol, and this typical variance is not seen until subjects reach 0.4 parts per thousand. This is at a level where you are not allowed to drive a car in Sweden, and means you are not able to concentrate for long periods of time and you are not focused. Reaction time is clearly a performance measure in the study’s context, so the night shift data shows decreased performance in all participants. This can be attributed to fatigue in terms of sleepiness, or to decreased capacity to concentrate as a result of fatigue. The latest is very clear when looking at the variance of the reaction time data after the night shift, as this was at times very large: A participant could have a number of short reaction times (approximately the same as the participants after a day shift), followed by a few very long reaction times (longer and more frequent than participants after the day shift). As the analysis of shift system effect on reaction time gave no significant result (only a tendency towards higher reaction time for the 6x6 shift system), there is evidence that night shifts cause this difference. This effect is also found in other domains, and is usually attributed to the biological rhythm of human beings. The result is supported by the KSS analysis for daytime versus night time, which gave significantly higher mean KSS scores during night time shifts.

Another interesting result of the reaction time data analysis was the differences between the two nationalities of workers on board: the Filipino participants had longer reaction times than the Swedish, although they reported lower KSS scorings. As the difference in KSS scorings most probably comes from cultural factors (discussed in 7.2.6), the reaction time differences are more complex to explain. Worth considering are factors such as proficiency in use of electronic devices or eagerness to obtain fast reaction times. The act of reacting to the visual stimuli on the Palm device was considered very simple, but not all participants may share this opinion. The explanation which seems most obvious is the higher sleepiness level which the participants from the Philippines may have experienced, also discussed in 7.2.6 and 7.2.7.

### 7.2.5 Actiwatch

These data are not fully analysed. What we see in the preliminary analysis is that the total amount of sleep seems to be lower for the 4/8 watch system, but that the sleep for the 6/6 system almost always is divided into two sleep periods. Of these, none seem to be over 5 hours and most are around 4:15–4:20. There are not enough earlier studies to entirely support the claim, but experience from the Karolinska Institute studies imply that adding two sleeps together (for example 2x4) does not constitute the sum of those sleeps, i.e. an 8-hour period, but rather less.

We also see low sleep efficiency (quality), around 75% for both watch systems. Anything below 80% can be classified as disturbed sleep. Participants themselves rated their sleep quality about 3.8 on a 5-grade scale. This indicates that they may not be aware that their sleep onboard is not of a very good quality.

For future work we will check if there is a correlation between measured sleep efficiency and participants' own judgement, from the diaries. The researchers are using a lot of time on an "objective" measurement, however, subjective rating might turn out to be just as good; Actiwatch or their own judgement. One possibility is that using the Actiwatch makes participants answer more honestly. Regarding the analysis of slept time and sleep efficiency, it is limited. Since many sleep diaries are not complete, for example, we cannot guarantee that the second sleep during one day really is a sleep. The participant could be staying really still (watching a movie?) or even have removed the Actiwatch.

### 7.2.6 Cultural issues

Looking at section 6.1.11 Influence of nationality of participants, we recognize how cultural differences may influence the results of this study. The participants from the Philippines are reporting lower KSS scores and getting higher reaction times. This probably means two things – they are more tired than the Swedish participants and they are underreporting their sleepiness. But there is no statistical difference in EOG. It also means that including these results in the analysis could perhaps skew the total results. More analysis will have to be performed here, and these results should be interpreted with care, as only 7 persons were in that group. However, during the field studies we observed, for example, a Filipinier officer filling in very low scorings on the KSS and later saying in conversation "I never sit down in the chair at night, I am afraid of falling asleep". Comments from these participants also indicate that they worry about being "found out" regarding sleepiness and perhaps this could mean trouble for them. One non-Swedish participant asked "if you find something, you will not tell anyone?" This also hints of a cultural effect, being a bit worried that what you say or report may have a negative influence on your employment (or that of others of your nationality).

Another possible contributing reason may be the translation of the Swedish KSS score texts into English, and the fact that English is not their first language.

Furthermore, non-Swedish crew members generally stay much longer on board. Their tour of duty can be 6–7 months, in comparison to Swedish crew, who stay on board 4–6 weeks. The amount of time spent on board will of course have an effect on a person’s general state, both sleepiness and other factors. This is implicitly evident in the higher reaction times of the non-Swedish participants.

Another cultural issue could hypothetically come into play. This concerns the seafarer culture. Some of the earlier research points to the beneficial influence of being more than one person on a watch or shift. Furthermore, during the dark hours on board ships, according to both national and international regulations, there has to be a look-out on the bridge, as well as the watch-keeping officer. On all ships we visited this look-out was present on the bridge. If one speculates that there may be ships on which this is not a standard practice, one may also speculate that the sleepiness levels would be higher on these ships, as well as having removed a human “watch alarm”.

### 7.2.7 Social and personal issues

We must also consider social issues – all people have a need to meet others and socialise. The lesser the free time, the smaller this possibility. Or, conversely, if someone feels the need to socialise, there will be less time left for resting and sleeping. It would not be a humane place to work if all the free time had to be spent alone, sleeping.

Generally, some time will be spent on personal affairs, such as eating, showering, using the bathroom and washing clothes. These are periods of time which, however brief, cannot be reduced or removed. Time should also be spent keeping fit and in reasonable shape. Time for these activities must be taken from the free time available, most of which is physiologically needed for sleep and rest.

Also, spending time on a ship means spending time away from home. Whether you have a family which you miss and worry about, or not, it is socially constraining to be on board. This gets worse the longer your turn on board is. Even with better communications on board in many ships, it must be hard to not be able to do what many today regard as normal, for instance using internet and telephones whenever you want to. Furthermore, the possibility to go ashore is severely restricted nowadays, due to the ISPS Code (International Ship and Port Facility Security Code) and other security restrictions. All these factors also affect the general wellbeing and therefore the fatigue levels of the seafarers. As such, they must be considered when making recommendations and regulations.

### 7.2.8 Example of combination of results, with SWP

The following image, Figure 46, shows two comparisons. In the top half, a chief officers’ (on the 6–12 watch) KSS and stress scores are combined. It is interesting to note two things; first, that several times during these 4 days, sleepiness levels are 7 or over. Secondly, when stress is high, sleepiness drastically drops – notice the third and the final set of scorings in the figure. This shows that stress will suppress fatigue. In the lower half of the figure, KSS scores are compared to the calculated sleepiness levels of the Sleep/Wake Predictor (SWP). The SWP is a mathematical model produced by the Karolinska Institute. It has been based on data from shift work ashore, and work is ongoing to adapt it better to shift work onboard. The SWP is reasonably accurate nevertheless, but note that it cannot predict the effects on fatigue of high workload/stress. Work will continue on refining this model, and it will be discussed in more depth in future reports.

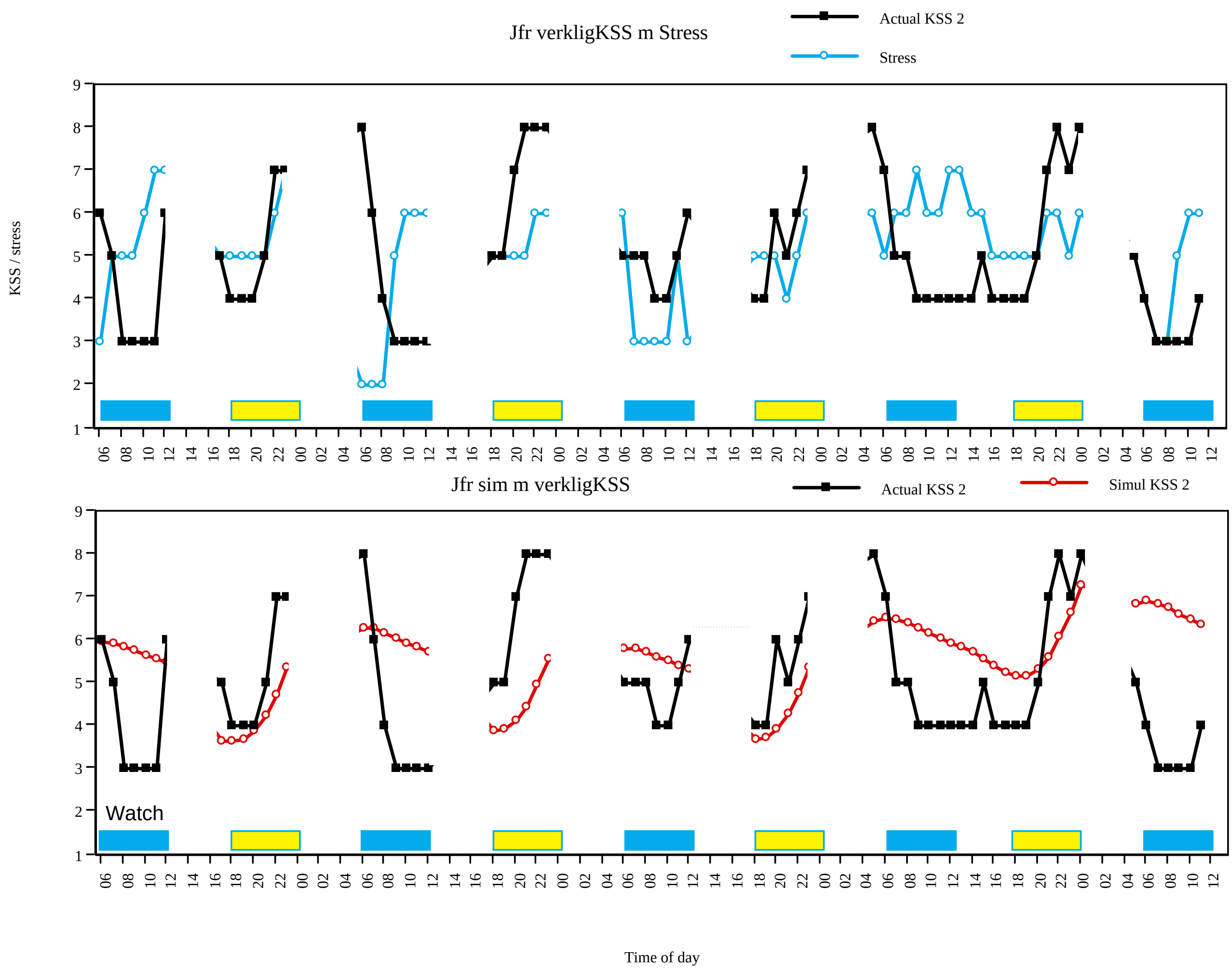


*Figure 46 KSS, stress and SWP scores for one participant.*

## 7.2.9 Result discussion – Interviews

There were no differences between shipping companies and shipping agencies regarding safety depending on fatigue. It seems that safety thinking is high in all the companies participating in the study.

All companies are aware of fatigue as a possible problem and some have made investments to reduce fatigue such as hired more personnel in some sensitive positions or doubled the watch on the bridge during periods of hard work or bad weather conditions. There was a comment that foreign crew members have to work longer periods on board than others, and the Swedish crewmembers then try to help them get more rest by working during their free hours. Since this is only hearsay, we cannot but speculate how this may influence fatigue in the crew as a whole.

All companies were willing to invest in “fatigue equipment” if there was a reduction of the insurance fees. Most of the companies did not know how much money they were willing to invest in “fatigue equipment”, the reason for this could be that there is no equipment on the market today and it is hard to estimate the costs. Another reason is that human resources departments do not have money for investments of their own; other departments in the company have the economic responsibility. If the insurance fees were reduced it would be a signal to the companies that it is worth to invest in “fatigue equipment”, hopefully due to safety matters and not only for the fee reduction.

Many ships have a warning system where the crew has to reset the system every 30 minutes or so. Two of the companies answered that this system is very disturbing for the crew on duty. A better system would be one which was only initiated when the person is tired. It is important to be aware that these systems do not remove the tiredness. It only alerts and/or disturbs people. It does not make them better decision makers or increase their reaction time as far as we know. It should be remembered that not only tsoe watch keepers who actually fall asleep are a risk, but those who are very tired and have to make decisions and keep their attention up.

If accidents decreased it was thought to be worth to make an investment. Only five companies gave a guess about the investment sum, it could be all from 5,000 to 25,000 SEK per crewmember and year or 100,000 SEK per ship. This is good news. Many companies show that they care about their employees, and take the issue of fatigue and related problems seriously.

## 7.3 Was the purpose fulfilled?

The project as a whole has an overreaching purpose; to highlight the issue of fatigue at sea, and provide data and tools for relevant stakeholders to address the issue. We saw that the dissemination of information and knowledge about fatigue has been beneficial for many stakeholders, and are pleased with that as one result of this project.

The purpose of the field study was to collect quantitative data about the fatigue level of bridge watch keepers on board ships, using several methods and techniques. Specifically, we wished to measure possible differences between the 6x6 and the 4x8 watch system. Although the statistical proof is missing, the constant trend of all results still indicate that 6x6 systems are more tiring and provide too little, and low-quality sleep. Therefore, the same situation may be assumed to exist in ships flying other flags, where on-board periods are substantially longer.

The purpose of the shipping company interviews was to interview persons in leading positions in shipping companies and shipping agencies about their attitude towards fatigue and fatigue monitoring. Questions that arise from that study are:

- How much are the insurance companies willing to invest in fatigue monitoring?
- What can other stakeholders do?

We wish to use these results and earlier work to devise innovative solutions for the shipping industry. The ultimate purpose is to construct solutions that lead to safe manning of ships while acknowledging economical constraints. A collection of recommendations, relevant for various stakeholders, will be published separately.

In sum, the project leaves us with many questions, but we have still fulfilled the purpose of raising and researching the issue of fatigue at sea. Forthcoming publications will contain further analysis, results and recommendations.

# 8 Conclusions

**The following is suggested by the results of questionnaires and diaries:**

1. Mates in the three-watch system are more satisfied with their working times and working situation.
2. Mates in the two-watch system are sleepier than mates in the three-watch system, especially in early morning and afternoon.
3. Most mates think they need at least 8 hours of sleep a day independent of watch system.
4. All mates are less sleepy and less stressed at home independent of watch system.

**The following is suggested by the results of EOG, KSS and reaction time tests:**

5. Although no statistical difference is found, all tendencies in the results point in the same direction: officers in the 6x6 watch system are more tired than the ones in the 4x8 system
6. The highest KSS ratings show that all work which is performed over and above the 6 hours lead to very high sleepiness levels and should be avoided.
7. KSS values are highest on night shifts.
8. 5.6% of all scorings are 7 and over. This means that during 83 hours participants were tired. During 39 hours they were very tired, staying awake with effort or fighting sleep.
9. 82% of the very high KSS values (over 7) is from 6x6 ships.
10. The most sleepy participants work two-shift.
11. Reaction times are longer for all participants after a night shift.
12. Variation in reaction time is higher for two-shift which suggests that they are more unfocussed.
13. Actiwatch data show that participants sleep approximately 6–7 hours per 24 hours independent of shift system.
14. The sleep on the two-watch ships is divided into two sleeps, very few of which is longer than approximately 4.5 hours. The only watch in the 4x8 system which approaches these low levels seems to be the 04–08/16–20 watch.
15. Sleep quality is low, and can probably be classified as disturbed, for both shift systems according to Actiwatch results.
16. Non-Swedish participants rate their sleepiness (KSS) significantly lower, but also have significantly longer reaction times after the night watch, which is contradictory.

**The following conclusions may be drawn from the interview study:**

17. Most Swedish shipping companies do not think fatigue is a problem (during normal conditions) – but would address it if they found it necessary.

18. Most would consider fatigue monitoring equipment, and believe that the crew would accept it.
19. All would install equipment if insurance premiums were lowered (say 30%).

**The following conclusions apply to the methods used:**

20. EOG does not add much useful information in this study and could perhaps be left out in similar studies.
21. Reaction time measurements can probably be reduced to 4 minutes.

> Good as they may be, training packages on fatigue are only a minor contribution to a major problem – making ships safe and efficient by a rational approach to safe manning. (Holder, 2006.)

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# Information about the study

## Project information to officers onboard

### Background to these trials

In Sweden the issue of fatigue connected to groundings and collisions is believed to be relatively small. Even so a large number of accidents and incidents seem to be related to fatigue, and the number of unknown cases can be large. There is very little information about how the watch systems 6-6 and 4-8 have an influence.

In this research project we want to study how the different watch systems influence the level of fatigue in bridge officers. We will do this by combining measurements on board with sleep diaries which are filled in by the participants. The project is a joint venture between VTI (the Swedish National Road and Transportation Research Institute) and the Karolinska Institute. It is financed by Swedish Maritime Administration, The Swedish Agency for Innovation Systems (VINNOVA) and The Swedish Mercantile Maritime Foundation. The study will be performed on approximately 12 ships.

### What your participation means

If you choose to participate, you will (depending on your work schedule) participate in one or several onboard studies. One of our researchers will follow the ship for about 7-10 days.

During your work period we ask you to fill in a Sleep diary when you go to bed and when you get up, and an Awake diary during and after your watch. They are one page each and contain a few questions.

You will get diaries to fill in at home. The purpose of this is to learn more about how your sleep is and how your sleepiness and stress levels are when you are ashore – so that we have something to compare your onboard values with.

During the last week before you go onboard and 3-7 days after you go ashore we ask you to fill in the Awake diary during the day and Sleep diaries after you awake from your sleep. The forms are very similar to those you will fill in onboard. In the Awake diary you will fill in your level of sleepiness and your level of stress. We are grateful if you fill these levels in as often as you can.

During the first day the researcher is onboard all details will be explained. You will also be asked to fill in a questionnaire about your sleep habits and general well-being. You will also perform a reaction time test on a palm computer, which takes a few minutes and will be performed on the first and last day of the researcher's visit.

During the time the researcher is onboard you will carry a so-called Actigraph which registers accelerations (how you move). It looks like a wrist watch and is worn 24 hours a day. Please do not submerge the watch under water or fluid for long periods of time, and please remove it when you take a shower. From your movements we can primarily analyse how good and how long your sleep has been during your free watch.

During your watch periods (while a researcher is onboard) you will also carry an EOG- equipment (EOG = elektro-oculo-gram ≈ registration of eye movements). This is an instrument which measures eye blinks through by 5-7 electrodes fastened to the skin around the eyes. This is performed by the researcher. The electrodes are connected by thin cables to a small data box which can be carried for example on a belt. You may remove the electrodes if you think they are disturbing your work, for instance if you leave the bridge to work on deck or similar. With eye movement registration it is possible to gain information on how tired a person is.

**Time plan**

The study is a 2-year project, 2005-2007. Several visits are planned to the same ship. Detailed planning will be performed with the company and the ship. Because ship's voyages generally are hard to predict there is no detailed time plan. You will get more information from your company and the researchers (contact info below).

**The right to decline participation and the registration of data**

Your participation is voluntary and you have the right to leave the study at any time without explanation. All data are de-identified before registration in a computer and all presentations will be done group-wise. Your integrity is protected by Swedish law (Personuppgiftslagen 1998).

**Do you want to know more?**

Please contact

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or

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**Agreement**

I acknowledge that I have read the above information and that I agree to participate in the study.

____________________________________

Place and date

____________________________________

Signature

____________________________________

Name

This form may be given to the researcher at the onboard visit

# Questionnaire concerning general health

Name:

1. Year of birth:

2. Marital status: ☐ married/cohabitant ☐ unmarried/living alone

3. Number of children living at home, 7 years old or younger:

4. Number of children living at home, older than 7 years :

5. How long have you been at sea? Approximately years

5a. I work as a (your position?)

5b. For how long have you had your present position? Approximately years

6. How long have you worked irregular working times including watch standing or other working times with night work? Approximately years

7. Do you have extra work (e.g. farming, business of your own, other extra work, etc.)

**beside your ordinary work**?

☐ yes, I work hours per month

☐ no

8. How do you like your present working hours?

☐ very little

☐ rather little

☐ neither little nor much

☐ rather much

☐ very much

9. How do you like your present work situation?

☐ very little

☐ rather little

☐ neither little nor much

☐ rather much

☐ very much

10. How do you like your present work tasks?

☐ very little

☐ rather little

☐ neither little nor much

☐ rather much

☐ very much

**Health**

11a. How do you think your general state of health has been the past year?

☐ very good

☐ rather good

☐ tolerable

☐ rather bad

☐ bad

11b. Have you used any of the following medicines (with or without prescription) the past 6 months? Tick one alternative for each type of medicine!

| | | Never | Seldom, a couple of times per year | Sometimes, a couple of times per month | Often, a couple of times per week | Always, Nearly every day |
|---|---|---|---|---|---|---|
| 11.1 | Sleeping pills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11.2 | Sedatives | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11.3 | Medication against depression | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11.4 | Medication against heart burn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11.5 | Medicines against pain or fever (e.g aspirin) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11.6 | Medication against high blood pressure | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11.7 | Medication against heart disease | ☐ | ☐ | ☐ | ☐ | ☐ |

12. Have you suffered from any of the following illnesses or troubles the past 6 months? If you answer ”yes”, please indicate if the troubles are slight or severe.

| | | No | Yes, slight | Yes, severe |
|---|---|---|---|---|
| 12.1 | Troubles from neck or shoulders | ☐ | ☐ | ☐ |
| 12.2 | Troubles from your back | ☐ | ☐ | ☐ |
| 12.3 | Other troubles from arms or legs | ☐ | ☐ | ☐ |
| 12.4 | Nervous problems | ☐ | ☐ | ☐ |
| 12.5 | Neurological disease (paralysis, epilepsy etc) | ☐ | ☐ | ☐ |
| 12.6 | Sleeping troubles | ☐ | ☐ | ☐ |
| 12.7 | Troubles from your eyes or with your vision | ☐ | ☐ | ☐ |
| 12.8 | Troubles from your ears or with your hearing | ☐ | ☐ | ☐ |
| 12.9 | Allergy (hay fever etc.) | ☐ | ☐ | ☐ |
| 12.10 | Eczema, skin troubles | ☐ | ☐ | ☐ |
| 12.11 | Asthma, breathing troubles | ☐ | ☐ | ☐ |
| 12.12 | Lung disease | ☐ | ☐ | ☐ |
| 12.13 | Cardiac infarction | ☐ | ☐ | ☐ |
| 12.14 | High blood pressure | ☐ | ☐ | ☐ |
| 12.15 | Vascular spasm | ☐ | ☐ | ☐ |
| 12.16 | Gastric or intestinal disease | ☐ | ☐ | ☐ |
| 12.17 | Troubles from the bile or liver | ☐ | ☐ | ☐ |
| 12.18 | Urinary tract infection | ☐ | ☐ | ☐ |
| 12.19 | Other illnesses of the kidney or urinary tract | ☐ | ☐ | ☐ |
| 12.20 | Diabetes | ☐ | ☐ | ☐ |
| 12.21 | Other illnesses | | | |

13. Have you suffered from any of the following troubles the past 6 months? If you answer ”yes”, please indicate if the troubles are slight or severe!

| | | Never | Seldom, a couple of times per year | Sometimes, a couple of times per month | Often, a couple of times per week | Always, Nearly every day |
|---|---|---|---|---|---|---|
| 13.1 | Tired in your head | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.2 | Headache | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.3 | Dizziness | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.4 | Restlessness | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.5 | Nervousness/uneasiness | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.6 | Depressed | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.7 | A feeling of that everything is meaningless | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.8 | Indifference | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.9 | Passivity | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.10 | Lack of initiative | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.11 | Pain in the stomach | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.12 | Feeling sick | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.13 | Palpitations | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.14 | Breathing problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.15 | Pain or a feeling of pressure in your chest | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.16 | Pain or stiffness in a joint or arms/legs | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.17 | Pain in your back | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.18 | Tense muscles | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.19 | Tense jaws | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.20 | Lack of appetite | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.21 | Hunger | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.22 | Heart burn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.23 | Diarrhoea | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.24 | Flatulence | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.25 | Constipation | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13.26 | Other? | | | | | |

**Sleep and fatigue**

14. How do you judge your general sleep quality?

☐ very good

☐ rather good

☐ Neither good nor bad

☐ rather bad

☐ very bad

15. Do you think you get enough sleep during work periods?

☐ Yes, definitely enough

☐ Yes, nearly enough

☐ No, somewhat insufficient

☐ No, clearly insufficient

☐ No, far from enough

16. Have you had the following problems **during the past 6 months** (**<u>during work periods</u>)?** Tick one alternative for every problem!

| | | never | Seldom, a few times per year | Sometimes, a few times per month | Most of the time, several times per week | Always, every day |
|---|---|---|---|---|---|---|
| 16.1 | difficulties falling asleep | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.2 | difficulties waking up | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.3 | repeated awakenings with difficulties returning to sleep | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.4 | loud snoring (according to other people | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.5 | nightmares | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.6 | not well rested at awakening | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.7 | premature (final) awakening | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.8 | disturbed/unrestful sleep | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.9 | too little sleep (less than 6 hours) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.10 | sense of being exhausted at the awakening | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.11 | tired/sleepy during work | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.12 | irritated and tired eyes | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.13 | unintended periods of sleep (nodding off) during work | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16.14 | having to fight against sleep in order to remain awake | ☐ | ☐ | ☐ | ☐ | ☐ |

17. Have you had the following problems **during the past 6 months** (**<u>during leisure</u>)?** Tick one alternative for every problem!

| | | never | Seldom, a few times per year | Sometimes, a few times per month | Most of the time, several times per week | Always, every day |
|---|---|---|---|---|---|---|
| 17.1 | difficulties falling asleep | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.2 | difficulties waking up | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.3 | repeated awakenings with difficulties returning to sleep | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.4 | loud snoring (according to other people | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.5 | nightmares | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.6 | not well rested at awakening | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.7 | premature (final) awakening | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.8 | disturbed/unrestful sleep | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.9 | too little sleep (less than 6 hours) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.10 | sense of being exhausted at the awakening | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.11 | tired/sleepy during leisure | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.12 | irritated and tired eyes | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.13 | unintended periods of sleep (nodding off) during leisure | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17.14 | having to fight against sleep in order to remain awake | ☐ | ☐ | ☐ | ☐ | ☐ |

18. How many cups of coffee do you approximately consume on a work day?

☐ None ☐ 1-2 cups ☐ 3-4 cups ☐ 5-6 cups ☐ 7 cups or more

**Sleep habits and diurnal rhythm**

19. Which one of the following statements fits in best?

☐ I can easily fall asleep both during the day and the evening.

☐ I have difficulties falling asleep during the day, but no difficulties in the evening.

☐ I have difficulties falling asleep both during the day and in the evening

☐ I have difficulties falling asleep in the evening, but no differences during the day.

20. Which one of the following statements fits in best?

☐ I have no difficulties waking up after sleeping both during the day and the night.

☐ I have difficulties waking up after sleep during the day but not after night sleep

☐ I have difficulties waking up after sleep both during the day and the night

☐ I have difficulties waking up after sleep during the night, but not after night sleep.

21. When would you prefer to rise (provided you have a full day's work – 8 h) if you were totally free to arrange your time?

☐ Before 06.30h
☐ 06.30 - 07.29h
☐ 07.30 - 08.29h
☐ 08.30h or later

22. When would you prefer to go to bed (provided you have a full day's work – 8 h) if you were totally free to arrange your time?

☐ Before 21.00h
☐ 21.00 - 21.59h
☐ 22.00 - 22.59h
☐ 23.00h or later

23. If you always had to go to bed at 2100h, how do you think it would be to fall asleep then?

☐ Very difficult – would lie awake for a long time
☐ Rather difficult – would lie awake for some long time
☐ Rather easy – would lie awake for a short time
☐ Easy – would fall asleep practically at once

24. If you always had to rise at 0600h, how do you think it would be?

☐ Very difficult and unpleasant
☐ Rather difficult and unpleasant
☐ A little unpleasant but no great problem
☐ Easy – no problem at all

25. When do you usually begin to feel the first signs of tiredness and need for sleep?

☐ Before 21.00

☐ 21.00 - 21.59

☐ 22.00 - 22.59

☐ 23.00 or later

26. How long time does it usually take before you “recover your faculties” in the morning after rising from a night’s sleep?

☐ 0 - 10 minutes

☐ 11 - 20 minutes

☐ 21 - 40 minutes

☐ More than 40 minutes

27. Please, indicate to what extent you are a morning or evening active individual.

☐ Pronounced morning active (i.e., morning alert and evening tired)

☐ To some extent morning active

☐ To some extent evening active (i.e., morning tired and evening alert)

☐ Pronounced evening active

28. How much sleep do you need? hours minutes

29. Except for sleep, do you think you get enough rest/relaxation during work periods?

☐ Yes, definitely enough

☐ Yes, nearly enough

☐ No, somewhat insufficient

☐ No, clearly insufficient

☐ No, far from enough

30. How often do you exchange watches on the bridge with a colleague?

☐ Never

☐ Seldom (a few times per year)

☐ Sometimes (a few times per month)

☐ Often (several times per month)

☐ Most of the time (nearly every week)

31. How are your possibilities for undisturbed recuperation, rest and sleep (depending on external factors, family or social reasons)?

- ☐ Definitely enough
- ☐ Nearly enough
- ☐ Somewhat insufficient
- ☐ Nearly insufficient
- ☐ Far from enough

THANK YOU FOR PARTICIPATING!

Other comments:

# Sleep Diary SLEEP DIARY -DAY the SUBJECT: _______

**I went to bed with the purpose of sleeping at ________and woke up at ______**

**How long did it take for you to fall asleep? _________hours _________ minutes**

When answering the questions below, please also use the intermediate alternatives, if appropriate.

**Sense at:**

| Bed-time: | Getting-up: | |
|---|---|---|
| 1 | 1 | very alert |
| 2 | 2 | |
| 3 | 3 | alert |
| 4 | 4 | |
| 5 | 5 | neither sleepy nor alert |
| 6 | 6 | |
| 7 | 7 | sleepy, not straining to staying awake |
| 8 | 8 | |
| 9 | 9 | very sleepy, fighting against sleep |

**Did you feel anxious/stressed at bedtime?**
5 not at all
4 a little
3 some
2 quite
1 very

**Was it hard to fall asleep?**
5 not at all
4
3 quite
2
1 very

**How have you slept?**
5 very well
4 quite well
3 neither nor
2 quite bad
1 very bad

**Disturbed sleep?**
5 not at all
4
3 some
2
1 very

**Did you wake up too early without being able to fall asleep again?**
5 no
4
3 a little too early
2
1 much too early

**Number of awakenings**
☐ 0 ☐ 5
☐ 1 ☐ 6 or more
☐ 2
☐ 3
☐ 4

**Time awake during period of sleep?**
5 none
4 a couple of minutes
3 10 – 30 min
2 3/4 – 1 hour
1 more than one hour

**Have you slept long enough?**
5 yes, definitely enough
4 yes, nearly enough
3 no, slightly too little
2 no, clearly too little
1 no, definitely too little

**How deep was your sleep?**
1 very light
2 quite light
3 neither nor
4 quite deep
5 very deep

**Easy to get up?**
5 very easy
4
3 neither nor
2
1 very hard

**Well rested?**
5 completely
4
3 quite
2
1 not at all

**Did you have some coffee or medicals during the day, and in that case, how much?**

☐ **Coffee; Number of cups:_______**
(write zero for no cup at all)

☐ **Medicals** **Amount?**
☐ sleeping pills _______
☐ painkillers _______
☐ other_____________________
☐ nothing

**Have you had any alcohol during the night?**
(Do not count beer of class I and II)

☐ no, nothing at all
☐ yes, one glass of wine/pint of beer
☐ yes, normal dinner drinking
(equals 1/2 a bottle of wine/2 pints of beer)
☐ yes, I have been party drinking
(more than 1/2 a bottle of wine)

**Did something special occur that you think might have disturbed the sleep?**
1 no
2 yes, the work hours
3 yes, hard physical activity
4 yes, wrong time for bed going
5 yes, worried of oversleeping
6 yes, illness/pain
7 yes, noise during sleep
8 yes, some other cause:________________
______________________________

**Was it something specific that caused the final awakening and getting up?**
6 nothing special (spontaneous awakening)
5 yes, the alarm clock (or alike)
4 yes, noise or alike
3 yes, toilet need
2 yes, pain
1 yes, other:______________________
_______________________

**Do you remember any dreams?**
☐ No
☐ Yes

**If yes, was it a nightmare?**
☐ Yes, I had at least one nightmare
☐ No

**Is there something you would like to add about the day or the sleep?**
____________________________________________________________
____________________________________________________________

# Awake Diary onboard

Personal code/name Position: Date (date starts at 00h):

Below is a table with three columns: One for each of the hour around the clock (make a check mark between the parentheses if you have been on watch), one where you fill in your level of sleepiness and one where you fill in your level of stress. Below the columns there are two boxes with descriptions of the scales for ”sleepiness” and ”stress”, respectively. In the columns **sleepiness** and **stress** we ask you to fill in (using the numbers given in the boxes below) how you felt during every hour of the watch and during off-duty periods (if you were awake). For the stress scale: use also the numbers 2, 4, 6, and 8 if suitable.

| **Time** | **Sleepiness** | **Stress** | **Time** | **Sleepiness** | **Stress** |
|---|---|---|---|---|---|
| 00h ( ) | ______ | ______ | 12h ( ) | ______ | ______ |
| 01h ( ) | ______ | ______ | 13h ( ) | ______ | ______ |
| 02h ( ) | ______ | ______ | 14h ( ) | ______ | ______ |
| 03h ( ) | ______ | ______ | 15h ( ) | ______ | ______ |
| 04h ( ) | ______ | ______ | 16h ( ) | ______ | ______ |
| 05h ( ) | ______ | ______ | 17h ( ) | ______ | ______ |
| 06h ( ) | ______ | ______ | 18h ( ) | ______ | ______ |
| 07h ( ) | ______ | ______ | 19h ( ) | ______ | ______ |
| 08h ( ) | ______ | ______ | 20h ( ) | ______ | ______ |
| 09h ( ) | ______ | ______ | 21h ( ) | ______ | ______ |
| 10h ( ) | ______ | ______ | 22h ( ) | ______ | ______ |
| 11h ( ) | ______ | ______ | 23h ( ) | ______ | ______ |

| **Sleepiness** | **Stress** |
|---|---|
| 1 extremely alert | 1 very low stress (I feel <u>very</u> relaxed and calm) |
| 2 very alert | 2 |
| 3 alert | 3 low stress (I feel relaxed and calm) |
| 4 rather alert | 4 |
| 5 neither alert nor sleepy | 5 neither low nor high stress |
| 6 some signs of sleepiness | 6 |
| 7 sleepy, no effort to stay awake | 7 high stress (I feel rather tense and under pressure) |
| 8 sleepy, some effort to stay awake | 8 |
| 9 very sleepy, great effort to keep awake, fighting sleep | 9 very high stress (I feel <u>very</u> tense and under <u>high</u> pressure |

**To be answered <u>after</u> the watches:**

Describe briefly what happened during the watches, for example departure. If on watch in port: workload? Did something special happen? If on watch at sea: weather, traffic density, workload. Also describe problems during the watches. ____________________

Did you experience anything of the ”symptoms” mentioned below) - try to estimate for how long (in minutes). Also fill in how long (in hours and minutes) the watches were

| | Number of minutes during watch 1 | Number of minutes during watch 2 |
|---|---|---|
| Heavy eyelids | | |
| ”gravel eyed” | | |
| Difficulty focussing the eyes | | |
| Nearly irresistible sleepiness | | |
| Difficulty holding the eyes open | | |
| Impaired performance | | |
| Periods during which you had to put in great effort to stay awake | | |

Watch 1 was ________________ hours and minutes long. (e.g. 4 h 30 min)

Watch 2 was ________________ hours and minutes long. (e.g. 5 h 00 min)

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VTI är ett oberoende och internationellt framstående forskningsinstitut som arbetar med forskning och utveckling inom transportsektorn. Vi arbetar med samtliga trafikslag och kärnkompetensen finns inom områdena säkerhet, ekonomi, miljö, trafik- och transportanalys, beteende och samspel mellan människa-fordon-transportsystem samt inom vägkonstruktion, drift och underhåll. VTI är världsledande inom ett flertal områden, till exempel simulatorteknik. VTI har tjänster som sträcker sig från förstudier, oberoende kvalificerade utredningar och expertutlåtanden till projektledning samt forskning och utveckling. Vår tekniska utrustning består bland annat av körsimulatorer för väg- och järnvägstrafik, väglaboratorium, däckprovningsanläggning, krockbanor och mycket mer. Vi kan även erbjuda ett brett utbud av kurser och seminarier inom transportområdet.

VTI is an independent, internationally outstanding research institute which is engaged on research and development in the transport sector. Our work covers all modes, and our core competence is in the fields of safety, economy, environment, traffic and transport analysis, behaviour and the man-vehicle-transport system interaction, and in road design, operation and maintenance. VTI is a world leader in several areas, for instance in simulator technology. VTI provides services ranging from preliminary studies, highlevel independent investigations and expert statements to project management, research and development. Our technical equipment includes driving simulators for road and rail traffic, a road laboratory, a tyre testing facility, crash tracks and a lot more. We can also offer a broad selection of courses and seminars in the field of transport.

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