International Shipbuilding Progress 71 (2024) 29–47
DOI 10.3233/ISP-230014
IOS Press

Assessment of navigators' ergonomic awareness and working conditions on navigation bridges

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Received 14 November 2023
Revised 30 April 2024
Accepted 15 May 2024

BACKGROUND: Merchant ships, despite huge technological progress, are still operated by qualified navigators. According to ergonomics principles, human is a part of the whole system and is affected by the surrounding environment.
OBJECTIVE: The purpose of the paper was to assess the ergonomic awareness of professional navigators, to understand their expectations towards navigation bridges and to check if they obtain enough support from their workplace.
METHODS: A special questionnaire was developed and 200 responses were obtained from seafarers with license of Officer Of the Watch or higher. Statistical analysis were carried out to find out relationships and differences between answers and groups of respondents.
RESULTS: Improper ergonomics and less than optimal working conditions were not isolated incidents and occurred to be rather common problem of the industry. The results suggest that ergonomic awareness is at relatively high level, however this knowledge is frequently not used in practice.
CONCLUSIONS: Poor design and lack of proper ergonomics training might contribute to commonly experienced signs of fatigue, pain episodes and therefore reduced performance of seafarers. Navigators find ergonomics important, however navigation bridges often do not meet ergonomics and comfort standards, therefore there is still a room for improvement in this area.

Keywords: Bridge ergonomics, ergonomic awareness, bridge design

1. Introduction

Numerous factors, including environmental, technological and organizational, affect human behaviour, activities and well-being at work [17]. Navigators are directly responsible for safety of the ships, cargo, crew and passengers, therefore it should be expected that their workplace allows to perform the duties in the most efficient way. Navigation bridges and the process of their design are often criticized for being technology-centred and not considering the vessel operations at all [10]. New technical solutions are meant to aid situation awareness of the navigators and make the ship

handling safer [11]. At the same time, analysis carried out by Bielić et al. [4] shows that as much as 31% of maritime accidents are associated with technology. Apart from safety of the ship, there comes also the problem of health and well-being of the seafarers, who work in the difficult environment and very often suffer from fatigue or stress. Undoubtfully, maritime accidents are complex and caused by combination of events [5], however poorly designed workplace or reduced performance of the navigators surely increase the probability of occurrence of such incidents. Since the human remains the operator of the merchant vessels nowadays, it might occur more critical to boost the performance, well-being and stimulate the senses of the person, rather than put all efforts into searching for new devices.

A large number of different, extending or partly covering each other, definitions of ergonomics exist [30]. In the end, ergonomics main purpose is to apply the knowledge of human characteristics to the design of systems or workplaces. People at work are surrounded by plenty of different factors, therefore environmental ergonomics is concerned with how they interact with the environment [22]. That includes all the physical, chemical, biological, organizational, social and culture factors surrounding a worker [18]. Ergonomic design can be defined as mapping from the human capabilities and limitations to system requirements [19]. Apart from the planning, organization and arrangement, the proper knowledge of workers is necessary to perform the duties in the most efficient and healthy way. In this case, ergonomic awareness should not be limited to knowledge that ergonomics exists. It is necessary to understand and execute its main principles to optimize own well-being and performance, subject to present situation.

The maritime sector is facing a global shortage of qualified officers competent to handle ships [7], therefore shipping companies should look for solutions to attract new employees and retain in-service crews [8]. Comfortable and ergonomic bridge can not only be attractive to the workers, but can also play a significant role in reducing the fatigue, lack of focus or the impact of improper lookout [26]. Nevertheless, studies regarding environmental influence on performance of seafarers are still rare. Thus, the main purpose of this paper is to investigate the ergonomic awareness through professional navigators and to check if they obtain enough support from their work environment and workplace design. To achieve the goals, special questionnaire was designed and responses of 200 professional navigators with Officer Of the Watch, Chief Officer and Master licenses were analysed.

1.1. Ergonomics on a navigation bridge

Merchant ships can be considered as complex socio-technical systems, where mariners interact with technology designated for increasing the efficiency of operations [24]. Thus, it is important to constantly support the operator, as the technological progress advances. Human element is currently included in the Strategic Plan for International Maritime Organization (IMO) for 2018 to 2023. According to

this, human element will be considered while reviewing, developing and implementing requirements and regulations. The well-being and needs of seafarers will be also taken into account by IMO [16]. Based on field observation, fatigue-related problems are common to seafarers nowadays, what can degrade cognitive skills, slow down reaction time or affect decision making [28]. Ships operate constantly around the clock and rely on watch patterns, therefore missing a proper rest and working in noisy, dynamic or stressful environment might seriously affect the performance of human. After taking over the watch, navigator is expected to provide the safety to the ship and maintain the highest level of focus.

Navigation bridge is the main command centre of the vessel and thus its key part [12]. Duties of a deck officer are complex and that is why workplace should provide adequate support to people, as described in International Convention for Safety of Life at Sea (SOLAS), Chapter V, Regulation 15 [13]. Those requirements are very general, however navigation bridge is additionally supported by non-mandatory standards and guidelines [27]. This includes but not limited to MSC/Circ.982: *Guidelines on ergonomic criteria for bridge equipment and layout*, IACS Recommendation No.95 *for the Application of SOLAS Regulation V/15 – Bridge Design, Equipment. Arrangement and Procedures* (*BDEAP*) and ISO 8468:2007 (*Ship's bridge layout and associated equipment – Requirements and guidelines*). All of above-mentioned documents cover the topic of work environment factors, including lighting, temperature, humidity and noise. With the sole exception of noise limitation since 2012, so the adoption of Code of noise levels on board ships, there are only recommendations, guidelines and other non-mandatory documents regulating environmental conditions on the navigation bridges.

2. Materials and methods

Questionnaires are not only popular research instruments, but also a cost effective way to collect data from large numbers of the population [21]. The total amount of seafarers serving worldwide onboard merchant ships in 2021 was 1892720 and this includes 857540 STCW-certified officers of all departments [2]. The research tool for this paper was the questionnaire of author's own design, containing a battery of 6 socio-demographical and 20 questions to study the working conditions on the bridge and the awareness of ergonomics. At the beginning of the form, respondents were provided with the short definition of ergonomics to avoid confusion in answers.

2.1. Questionnaire development

The questionnaire was developed based on the document *MSC/Circ.*982: *Guidelines on ergonomic criteria for bridge equipment and layout*, International Convention of Standards of Training, Certification and Watchkeeping (STCW), observations from own visits on different ships and consultations with experienced captains. Full

questionnaire in English is presented in Appendix A. Due to the complex goals to be achieved in this research, questions were designed with various purposes, namely:

- Questions 1, 4 and 5 were related to the standard of comfort at workplace that was experienced by the navigators on their ships (developed based on observations and consultations);
- Questions 2 and 3 were related to pain episodes that were experienced by navigators during or immediately after duties (developed based on observations and consultations);
- Questions 6, 7, 8, 9 and 10 were related to working conditions on the bridges in terms of work environment (developed based on guidelines included in MSC/Circ.982);
- Questions 11 and 18 were related to possible influence of bridge ergonomics on work overload and fatigue (developed based on observations, consultations and guidelines included in MSC/Circ.982);
- Questions 12, 13, 14, 15, 16 and 17 were related to ergonomic awareness of navigators (developed based on STCW, consultations and basic ergonomic principles);
- Question 19 was included to obtain opinion from navigators regarding potential impact on their loyalty to the company after adaptation of the bridge to their individual ergonomic needs;
- Question 20 was included to obtain opinion from navigators regarding their compliance with ergonomic principles in practice.

2.2. Sample and data collection process

The questionnaire was distributed in online form, along with another one, also related to bridge ergonomics, designed in a way preventing incomplete responses. The survey form could be filled whether in English or in Polish, accordingly to respondent's preferences. The questions were the same in both languages, allowing consolidation of the answers after data collection process. The target respondents are very specific group of professionals, therefore to minimize the risk of bias and to obtain desirable level of confidence for this survey, it was deemed to be necessary to distribute online questionnaires via crewing agencies and shipowners.

The distribution started on 16 December 2021 and finished on 25 August 2022, resulting in 200 responses from the navigators holding the license of officer of the watch or higher. The participants were studying for their profession in 13 different countries. Each person was asked to fill the survey questionnaire once and all responses were checked manually to determine if they were filled correctly. It was found that one received form might contain doubtful or inconsistent answers, as the total time spent at sea in the rank of officer or higher, compared to the age of respondent, suggests obtaining such license before turning 18 years old, contrary to STCW requirements [14]. To achieve the highest quality of research, it was decided to remove this response from the analysis, so 199 were taken into consideration. The general characteristics of the sample are shown in Table 1.

Table 1
Sample characteristics

Parameter	*N*	*Distribution*
Rank (present or last ship):	199	
Officer Of the Watch (3rd Officer/ 2nd Officer/ OOW)		103.0 (51.8%)
Master		52.0 (26.1%)
Chief Officer		37.0 (18.6%)
Junior Officer / Apprentice Officer or equivalent		6.0 (3.0%)
Ordinary Seaman		1.0 (0.5%)
Age	199	36.0 (28.0, 53.0)[1]
Study place as navigator:	199	
Africa		21.0 (10.6%)
Asia		13.0 (6.5%)
Europe		165.0 (82.9%)
Highest license obtained:	199	
Officer Of the Watch (OOW) license or equivalent		85.0 (42.7%)
Master license (master)		75.0 (37.7%)
Chief Officer (CO) license		39.0 (19.6%)
Total sea-time in ranks of OOW + CO + Master	199	8.0 (2.0, 20.0)[1]
Type of navigating ship (present or last):	199	
Dry ship		93.0 (46.7%)
Wet ship		87.0 (43.7%)
Passenger		10.0 (5.0%)
Offshore		9.0 (4.5%)

[1]Median (the first quartile (25%), the third quartile (75%)).

2.3. Statistical environment and analysis

Analyses were conducted using the R Statistical language (version 4.1.1) [25] on Windows 10 pro 64 bit (build 19044). The significance level of the statistical tests in this analysis was set at $\alpha = 0.05$. The p-value was calculated using Holm's correction method for multiple comparisons (p_{adj}). The distribution of measures of central tendency for numerical variables was expressed as median (the first quartile (25%), the third quartile (75%)) ($Mdn\,(Q1, Q3)$). For nominal variables, the distribution was determined by reporting the frequency of each category and the percentage of the total (n). The effect size for estimating the relationship between nominal variables was determined using the phi measure (φ). The significance of differences between the means of two independent groups for numerical variables was determined using the Wilcoxon rank sum test [29]. For three or more independent groups, the Kruskal–Wallis rank sum test [20] was used. The significance of differences between pairs of groups was tested using Dunn's test [6]. For two categorical variables, significance was tested using Pearson's chi-square test [23] or Fisher's exact test [9]. Multiple

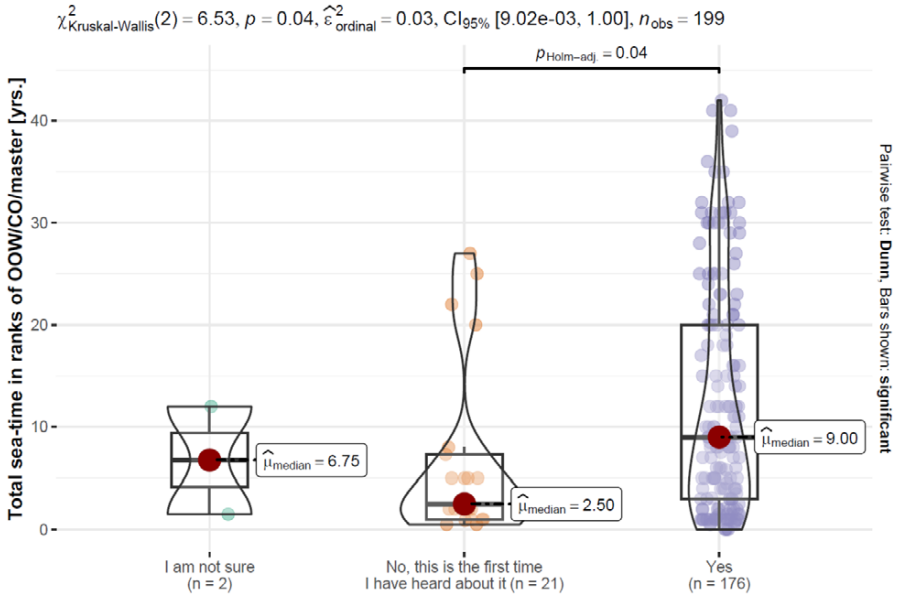

Fig. 1. Total see-time in ranks of OOW/CO/master by answers to the question "*Did you know the definition of ergonomics before?*" together with an estimate of the differences between the groups.

comparisons for post-hoc tests were performed using the method of Benjamini and Hochberg [3].

3. Results

Knowledge of the concept of ergonomics was reported by 176 (88.4%) subjects. Lack of knowledge about ergonomics was most evident in the group of young respondents ($Mdn = 28.0$ years ($Q1 = 26.0$, $Q3 = 42.0$)) with a significantly shorter total time at sea ($Mdn = 2.5$ years ($Q1 = 1.0$, $Q3 = 7.3$)), as shown in the Fig. 1. Those familiar with the concept of ergonomics were significantly more likely to report an association between non-optimal bridge working conditions and fatigue (n = 130, 73.9%), compared to the group without knowledge of ergonomics (n = 10, 46.7%) ($p_{adj} = 0.014$, $\varphi = 0.25$).

In response to the question regarding optimal condition for observing external surroundings, the correct option *"darker room than outside"* was chosen by 164 (82.4%) of the subjects. Those who answered correctly also showed a significantly higher percentage of support for the statement that various ergonomic factors on the bridge have an impact on the effectiveness of work and the safety of the ship (n = 146, 84.6%), compared to the group of those who did not pay attention (n = 1,

33.3%) ($p_{adj} = 0.019$, $\varphi = 0.32$). In addition, the participants with the correct answer showed a higher interest in learning about the effects of ergonomics on working conditions (n = 135, 82.3%) than the group with the incorrect answer "*brightness should be the same outside as inside"* (n = 16, 61.5%) ($p = 0.033$, $\varphi = 0.18$).

Sensory adaptation to current conditions prior to bridge watch was described as necessary in 191 (96.0%) subjects. Presence of red lights on the bridge, recommended by IMO and directly related to dark adaptation [15], was reported by 136 (68.3%) navigators. The factor of having red lights depended on the type of ship, although there are no differences in guidelines or regulations in this area. The percentage of red lights on wet ships (n = 78, 89.7%) was significantly higher than on dry ships (n = 48, 51.6%) ($p_{adj} < 0.001$, $\varphi = 0.42$), offshore ships (n = 5, 55.6%) ($p_{adj} = 0.048$, $\varphi = 0.31$) and passenger ships (n = 5, 50%) ($p_{adj} = 0.025$, $\varphi = 0.37$).

3.1. Pain episodes during or after duties

Back pain, knee pain, shoulder pain or muscle pain were experienced by 82 (41.2%) navigators in a relatively young age group ($Mdn = 34.0$ years ($Q1 = 27.0$, $Q3 = 48.8$)), with a total sea time in the OOW/CO/Master ranks below the sample average ($Mdn = 5.9$ years ($Q1 = 2.0$, $Q3 = 12.0$)). Only 31 (37.8%) of subjects in the group with pain episodes reported that the navigation bridge met their expectations for comfort. This percentage was significantly lower than in the group without pain episodes (n = 74, 74.0%) ($p_{adj} < 0.001$, $\varphi = 0.37$).

Those with pain episodes were also significantly more likely to report too loud and irritating sounds (alarms, GMDSS communications, etc.) on the bridge than in the group without pain episodes ($p_{adj} = 0.039$, $\varphi = 0.32$). Pain in head, eyes, neck were experienced by 77 (38.7%) subjects in a relatively young age group ($Mdn =$ 33.0 years ($Q1 = 28.0$, $Q3 = 41.0$)), with a total sea time in the OOW/CO/Master ranks below the sample average ($Mdn = 5.0$ years ($Q1 = 2.0$, $Q3 = 10.0$)). 57.1% of these people also suffered from pain in the back, knees, shoulders and muscles.

More than half of those with pain (n = 43, 52.4%), reported being overloaded during navigation watch and tasks such as constantly adjusting the brightness of equipment or adjusting the volume/temperature were annoying/distracting for them. This proportion was significantly higher compared with those without pain ($p_{adj} < 0.001$, $\varphi = 0.32$). Only 33 (42.9%) of subjects in the group with pain episodes reported that the navigation bridge met their expectations for comfort. This percentage was significantly lower than in the group without pain episodes (n = 72, 68.6%) ($p_{adj} = 0.002$, $\varphi = 0.26$).

3.2. Work environment and most disruptive factors

Different types of vibrations can be experienced onboard vessels, high-frequency vibrations are often related to rotating mechanical equipment, while low-frequency

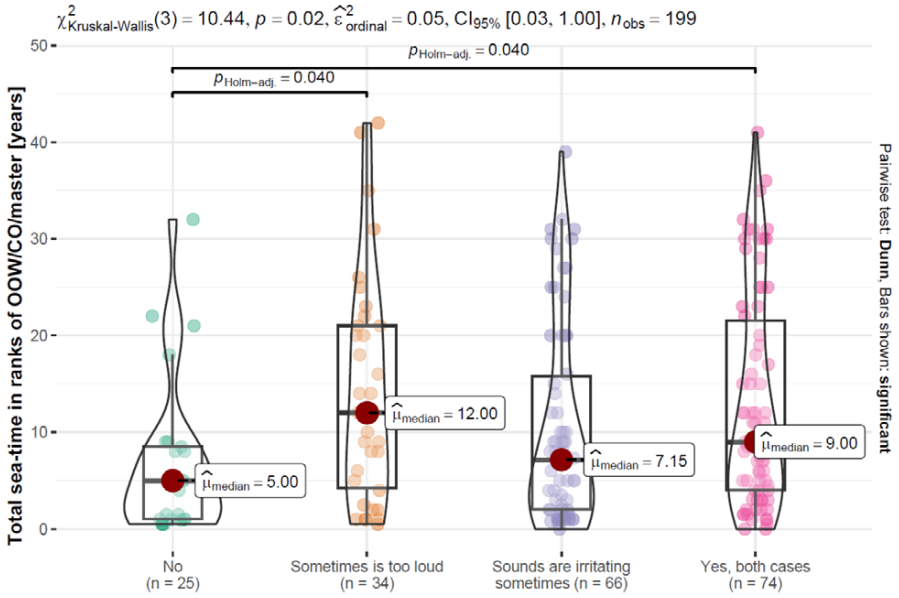

Fig. 2. Total see-time in ranks of OOW/CO/master by answers to the question "*Do you feel that sometimes on the bridge it is too loud or sounds there are irritating* (*for example because of alarms or GMDSS communication*)?" together with an estimate of the differences between the groups.

can be also caused by vessel motions on waves [1]. Rolling (n = 103, 51.8%) and vibration caused by machinery (n = 42, 21.1%) were mentioned among the greatest distractions while working on the navigation bridge. The disruptive factors were not significantly associated with the other sample variables. Loud or annoying noises were reported by 174 (87.4%) respondents, including loud noise alone by 34 (17.1%) and annoying noise alone by 66 (33.2%) subjects, both types of noise were reported by 74 (37.2%) subjects. Absence of noise annoyance was pronounced in the group of individuals with significantly shorter time as OOW/CO/Master (*Mdn* = 5.0 years (*Q*1 = 1.0, *Q*3 = 8.5)) compared with time as OOW/CO/Master of individuals with high noise levels (*Mdn* = 12.0 years (*Q*1 = 4.2, *Q*3 = 21.0)) ($p_{\text{adj}} = 0.040$), as well as with the time spent in ranks of OOW/CO/Master by individuals who had high levels of both types of noise annoyance (*Mdn* = 9.0 years (*Q*1 = 4.0, *Q*3 = 21.5)) ($p_{\text{adj}} = 0.040$). The total sea-time mentioned above together with an estimate of the differences between the groups is presented in the Fig. 2.

Those who reported loud noise along with disruptive noise indicated that their expectations of comfort while working on the bridge were significantly lower (n = 32; 43.2%), compared with the group that reported no noise (n = 23; 92.0%) ($p_{\text{adj}} < 0.001$, $\varphi = 0.43$). Also the percentage of comfort with reporting disruptive noise only (n = 39; 59.1%) was significantly lower (n = 32; 43.2%) compared with the group that reported no noise ($p_{\text{adj}} = 0.007$, $\varphi = 0.32$). Those who reported loud

noise along with annoying noise reported significantly higher levels of fatigue (n = 60; 81.1%) compared with the group that reported no noise (n = 12; 48.0%) (p_{adj} = 0.016, $\varphi = 0.35$).

The lack of ability to regulate the temperature on the bridge was reported by 45 (22.6%) subjects, in addition to the lack of knowledge on this subject by 5 (2.5%), mainly elderly ($Mdn = 58.0$ years ($Q1 = 34.0$, $Q3 = 58.0$)). In addition, 32 (16.1%) respondents stated that the air conditioner works too hard, despite the possibility to regulate the temperature. In this group, there was a significantly higher proportion of subjects (n = 18; 56.2%) who reported the temperature difference between the height of the feet and the height of the head, compared to the group with properly functioning air conditioning (n = 25; 21.4%) ($p_{adj} = 0.002$, $\varphi = 0.32$). The ability to regulate temperature depended on the type of vessel. Local bridge temperature management was most frequently lacking on passenger ships (n = 6; 60%), a proportion was significantly higher than that of offshore vessels (n = 0; 0%) ($p_{adj} = 0.022$, $\varphi = 0.73$) and wet vessels (n = 19; 21.8%) ($p_{adj} = 0.017$, $\varphi = 0.42$).

Differences in the air in terms of humidification from a comfortable level were reported by 115 (57.8%) navigators, of whom 7 (3.5%) stated that the air on the bridge was too humid, for 49 (24.6%) the air was considered too dry, while for 59 (29.6%) both of the above cases were reported. The differences between the level of humidification and the comfortable level were significantly dependent on the level of comfort while working on the bridge. Namely, the percentage of comfort expectations fulfilled when the air was optimally humidified (n = 62; 73.8%) was significantly higher than when the air was too dry (n = 21; 42.9%) ($p_{adj} = 0.004$, $\varphi = 0.31$) or too dry and too humid (n = 30; 50.8%) ($p_{adj} = 0.023$, $\varphi = 0.24$). When the air alternated between too dry and too humid, navigators reported fatigue significantly more often (n = 48; 81.4%) than when the air was optimally humid (n = 52; 61.9%) ($p_{adj} = 0.040$, $\varphi = 0.26$).

A noticeable temperature difference between head and leg height was reported by 58 (29.1%) subjects. Such situation was not dependent on the type of ship and was mainly related to the operation of the air conditioning system. A noticeable temperature difference was significantly more frequent (n = 18; 31.0%) in a very strongly operating air conditioner compared to a normally operating one (n = 14; 9.9%) ($p_{adj} = 0.002$, $\varphi = 0.32$). Those who worked under conditions of greater temperature variation were significantly more likely to report fatigue (n = 47; 81.0%) compared to those who worked under normal conditions (n = 94; 66.7%) (p_{adj} = 0.035, $\varphi = 0.19$).

3.3. Bridge ergonomics versus fatigue

Potential increase of fatigue due to less than optimal conditions on the bridge were reported by 141 (70.9%) navigators. The degree of fatigue did not depend on age or total time spent at sea. The group with fatigue symptoms was characterized by a significantly lower degree of fulfillment of the individual needs of such a bridge in

terms of work comfort (n = 71; 50.4%) compared to the group of subjects without fatigue symptoms (n = 30; 85.7%) ($p_{adj} < 0.001$, $\varphi = 0.29$). As mentioned earlier, fatigue levels were affected by, among other things, levels of loud and distracting noise (due to alarms or GMDSS communications), air on the bridge that was too dry or too humid, and temperature differences at leg and head level.

The degree of awareness that various ergonomic factors on the bridge have an impact on the effectiveness of your work and the safety of the ship was significantly higher among those with fatigue symptoms (n = 131; 92.9%), than among those without fatigue symptoms (n = 27; 77.1%) ($p_{adj} = 0.015$, $\varphi = 0.23$). The proportion of affirmative responses in the fatigued group to the question of whether task overload during navigation watch and tasks such as constantly adjusting the brightness of equipment or adjusting the volume/temperature were annoying/distracting was significantly higher (n = 75; 53.2%) compared to the non-fatigued (n = 9; 25.7%) ($p_{adj} = 0.008$, $\varphi = 0.28$).

An influence of various ergonomic factors on the bridge on the effectiveness of the work and the safety of the ship was found by 175 (87.9%) respondents. The distribution of affirmative responses did not differ by rank, license, age, time at sea or by vessel type. Those who were aware of the effects of ergonomics on job performance were more likely to report that uncomfortable working conditions on the bridge affected fatigue levels (n = 131; 74.9%) than the group who reported no effects of ergonomics on job performance (n = 5; 45.5%) ($p_{adj} = 0.018$, $\varphi = 0.25$) and those who had no opinion (n = 5; 38.5%) ($p_{adj} = 0.009$, $\varphi = 0.29$).

Frequent adjustment of work environment on the bridge was considered to cause overloads while working on the bridge or described as annoying/disturbing by 148 (74.4%) navigators. Those who reported overloads were significantly more likely to report the presence of muscle, back, or joint pain (n = 43; 46.2%) compared to those who did not report overloads during duty on the bridge ($p_{adj} = 0.004$, $\varphi = 0.32$). The groups of individuals who reported being overloaded (n = 44; 47.3%) generally had significantly lower levels of fulfillment of individual expectations for comfortable working conditions than those who did not report being overloaded (n = 37; 78.7%) ($p_{adj} = 0.003$, $\varphi = 0.30$). The same was true for fatigue level, which was significantly more often reported in overloaded conditions (n = 75; 80.6%), than in comfortable working conditions (n = 25; 53.3%) ($p_{adj} = 0.010$, $\varphi = 0.31$).

3.4. Training and willingness to study ergonomics

Mostly, the navigation bridge was considered a place that requires increased activity of the senses (n = 139; 69.8%), significantly less often as the place where navigators can rest (n = 38; 19.1%). A minority (n = 22; 11.1%), primarily older individuals with longer total time in the ranks of Officer Of the Watch, Chief Officer or Master, could not characterize their attitudes toward working on the bridge, it is shown accordingly in the Fig. 3 and Fig. 4. The characteristics of work on the navigation bridge did not depend on the rank, license of the respondent or the type of the

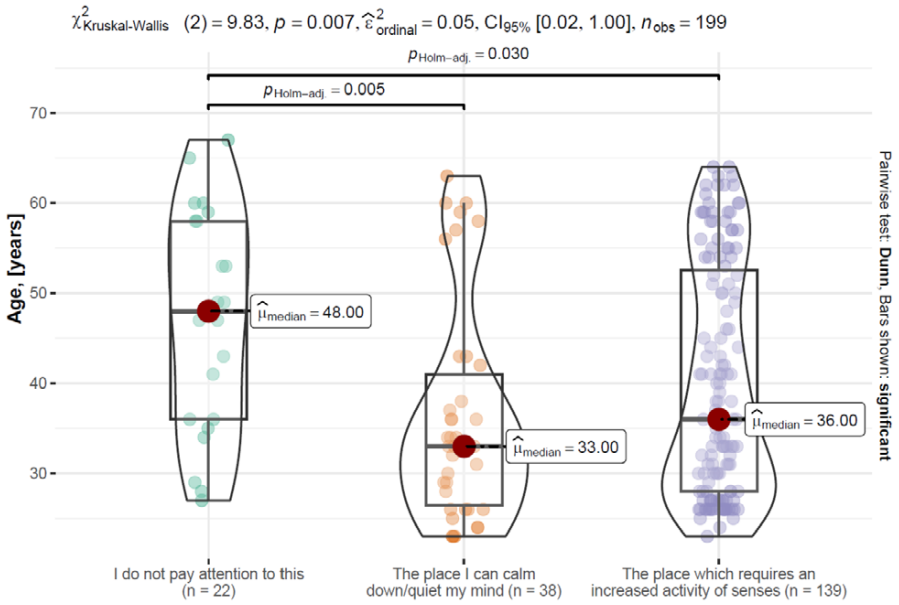

Fig. 3. Age distribution of respondents by answers to the question "*Is the bridge a place where you can calm down/quiet your mind or a place which requires an increased activity of senses?"* together with an estimate of the differences between the groups.

ship. In contrast, those who characterized bridge as a place that requires increased sensory activity showed significantly greater interest in learning about ergonomics and its effects on work than the group who could not characterize their attitudes toward bridge work ($p_{\text{adj}} = 0.002$, $\varphi = 0.30$).

Ergonomics training related to the bridge ergonomics was attended by 52 respondent (26.1%), of whom 35 (17.6%) had received such training at a college, university or courses. Willingness to learn about the concept of ergonomics and ergonomic implications for work was expressed by 157 (78.9%) individuals. The proportion of navigators willing to do so was similar regardless of rank, license type, age or total sea-time. In contrast, the percentage of those willing to learn who worked on wet ships (n = 79; 90.8%), was significantly higher than the percentage of those who worked on dry ships (n = 62; 66.7%) ($p_{\text{adj}} = 0.001$, $\varphi = 0.46$).

Those interested in ergonomics were significantly more likely to consider the bridge a place requiring increased sensory activity ($p = 0.001$, $V = 0.27$), also more likely to give correct answers regarding the brightness level outside/inside for the best observation ($p = 0.049$, $V = 0.20$). In summary, only 72 (36.2%) of respondents share the opinion that navigators comply with the ergonomic principles during the watches on the bridge.

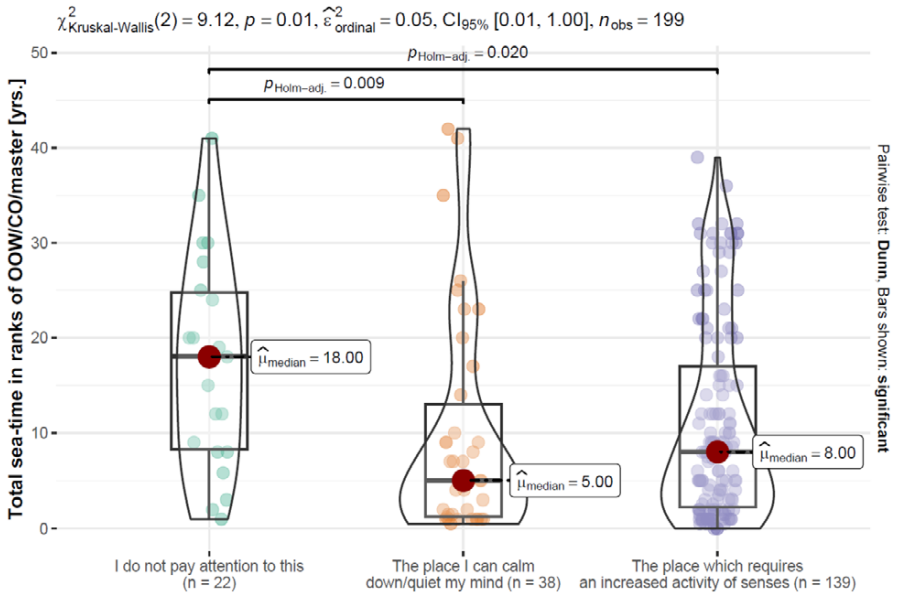

Fig. 4. Total see-time in ranks of OOW/CO/master by answers to the question "*Is the bridge a place where you can calm down/quiet your mind or a place which requires an increased activity of senses?*" together with an estimate of the differences between the groups.

3.5. Fulfilment of individual comfort needs on the bridges and employee loyalty

41.7% (n = 83) of the respondents stated that the navigation bridges do not meet the requirements for comfortable work, while more than half of them (n = 54; 65.1%) belong to the watch officer group. For the other positions (Chief Officer, Master or other), the majority pointed out that the requirements of the bridges are met in terms of working comfort. The degree of fulfilment of comfort needs did not depend on subjects age, total sea time in the OOW/CO/Master ranks or ship type.

For 128 (64.3%) respondents, adapting the bridge to individual ergonomic needs has an impact on loyalty and commitment to the company. These subjects were more likely to notice fatigue related to bridge working conditions. In addition, respondents in this group (n = 119; 93%), were significantly more likely to indicate that adapting the bridge to respondents' individual ergonomic needs would have a significantly greater effect on their loyalty and retention to their employer than the group of respondents who indicated no ergonomic effect (n = 35; 76.1%) ($p_{adj} = 0.023$, $\varphi = 0$). Adapting the bridge to subjects individual ergonomic needs in non-comfort group would significantly higher affect their retention to their employer (n = 65; 78.3%). More than 70% of respondents with pain episodes said that adapting the bridge to their individual ergonomic needs would affect their loyalty and retention to their employer, only 15.9% said it would have no effect on their commitment to the company.

Individuals with good knowledge of ergonomics reported a significantly greater impact on loyalty and commitment to the company when working conditions addressed individual ergonomic needs (n = 119; 68.0%) compared to individuals without ergonomics knowledge ($p = 0.025$, $\varphi = 0.20$). The effects of adapting the navigation bridge to individual ergonomic needs on loyalty and commitment to the company in the survey groups OOW (n = 63; 74.1%) and Chief Officer (n = 28; 71.8%) had significantly higher percentages of positive responses compared to the Master group (n = 37; 49.3%) with $p_{\text{adj}} = 0.018$, $\varphi = 0.27$ and $p_{\text{adj}} = 0.003$, $\varphi = 0.29$, respectively. The degree of loyalty was not related to a person's age or total time at sea.

4. Discussion

Based on the carried out questionnaire study, it can be concluded that awareness of the concept of ergonomics among professional navigators is at relatively high level (declared by 88.4%), however the knowledge is rarely applied in real-life scenarios. In general, the respondents were aware of hazards related to improper ergonomics and the impact it can have on their performance and duties (87.9%). The majority of them indicated the necessity of adaptation of senses subject to present conditions prior taking over the watch. As another matter of safety, 82.4% of participants correctly answered for the question regarding optimal lighting conditions inside the wheelhouse to effectively monitor surroundings of the ship visually. To perform this duties most effectively, inside should be darker than outside. Regardless the theory, it can be difficult to achieve during night-time, where a lot of sources of light are present on the bridge.

It was confirmed that modern problem of fatigue is present and common onboard merchant ships. This can be dependent on many factors, including reduced crews and minimized time spent in ports to keep operations cost-efficient. It was however reported by 70.9% navigators that less than optimal conditions on the bridge can potentially increase their fatigue. Management of work environment is undoubtedly part of maintaining safe navigational watch, however frequent adjustments of brightness, temperature and volume was considered as disturbing or even contributing to task overload by 74.4% of respondents. The worryingly low level of compliance with ergonomic principles during duties on the bridge might be caused not only by lack of proper knowledge or persistence, but also complex responsibilities not directly related to navigation.

4.1. Shifting the needs to comfort and well-being

It should not be underestimated that 41.2% respondents experienced back, knee, shoulder or muscle pain, while 38.7% declared pain in head, eyes or neck during or immediately after duties on the wheelhouse. In both cases, the percentage of those

who reported that navigation bridge met their expectation for comfort was significantly lower in groups that experienced pain, than in groups without pain episodes. Those issues might be related to intensive work, as 69.8% of navigators considered bridge as a place that requires from them increased activity of senses. Regardless the workload or required focus, 41.7% of respondents were not satisfied in their working conditions, as their workplaces did not meet their individual requirements for comfortable work. The factors that had impact on such statements might be related to improper lighting, lack of local temperature adjustment and loud or annoying noises. Some of the issues, like rolling or vibrations from machinery, are impossible to be completely prevented by the design of the wheelhouse, however efforts should be made to minimize their negative influence, for example with shock mitigation seats or floor mats. Moreover, navigators spend several hours continuously on the bridges during the watches, therefore the risks of ergonomic related problems are increased due to lack of breaks.

The important result obtained in this research is related to employee loyalty, as the market faces global shortage of qualified officers. Adapting the bridge to individual ergonomic needs would have an impact on commitment to the company for 64.3% navigators, as directly stated by respondents. That suggests that people tend to care for their comfort and well-being, having in mind that performing the job of navigator does not need to result in musculoskeletal disorders or headaches.

4.2. Training should be supported by the design

The fact that only 26.1% of navigators received any training in bridge ergonomics is thought-provoking in the shadow of low level of compliance with ergonomic principles during watches. The issue is to be considered as a global problem, as the respondents were professionals studying for their job in 13 different countries. This is however not only related to university or college courses, but also to employers. Shipowners are definitely capable to take proactive actions to eliminate dangers related to improper ergonomics on navigation bridges to support health of seafarers, reduce fatigue and promote good habits. Moreover, 78.9% of respondents reported willingness to study concept of ergonomics and ergonomic implications for work. This might suggest that seafarers would like to be guided more directly in the future and it might be reasonable to consider implementing ergonomics training in International Convention of Standards of Training, Certification and Watchkeeping (STCW). This might include not only theoretical but also practical exercises on navigation bridge simulators, commonly used worldwide. Navigators could be instructed how to properly menage their workplace subject to ergonomic needs and outdoor conditions, including adjustment of brightness, volume or temperature.

It is understandable that some of vessels, for example those built before adoption of ergonomic guidelines, might not fully support proper ergonomics. Therefore at least sufficient training should be provided to the navigators in order to minimize their fatigue and eliminate unhealthy habits. In recent years, a lot of emphasis

has been put on technological progress of navigational equipment but it should be highlighted that to operate ship in a safe manner, human surrounded by dozens of environmental factors should be capable of taking a proper decisions. One of the purposes of raising ergonomic awareness of navigators is to effectively manage the wheelhouse indoor environment in order to improve own performance.

5. Conclusions

Obtained results might be used as a guidance for shipowners where to look for potential investments, in order to increase the level of employee satisfaction. The important aspect is not only to provide the highest quality of navigational equipment, but also to create the environment that allows comfortable use of such devices. The profits from investments in ergonomics might not be readily apparent to the companies, as they are hard to measure. Apart from potentially increased performance of navigators, attracting employees can be definitely considered as one of the main benefits.

The research carried out using a self-designed questionnaire allowed to better understand the ergonomic awareness of professional navigators, which is considered to be at relatively high level. As occurred, very often the knowledge is not used in practice. Seafarers work in difficult environment, away from their families and under stress or time pressure. Properly applied ergonomics on the navigation bridge might result not only in improvement of comfort but also in increased performance of human, which is considered a key element in the collision avoidance and safe voyage execution. The awareness should be raised not only through navigators, but also companies. With the fast technological progress it is important to control the working environment and benefit from it in the most effective way.

The navigators suffer from different problems in their work, however issues related to improper ergonomics or not comfortable workplace occurred as common. Apart from the design, a training is one of the methods to be considered as the prevention of ergonomic-related incidents. Further studies are required to assess the real scale of the problem and the impact on performance of mariners, however this paper definitely showed that bridge ergonomics is considered important by the professional navigators and that there is still potential for improvement in this area.

Funding

This paper was made open access with financial support from Stichting Bijlboegfonds.

Conflict of interest

The author has no conflict of interest to report.

Author contributions

The author confirms sole responsibility of the following: conception; performance of work; interpretation of data; writing the article.

Appendix

Table A.1 below contains questionnaire distributed online to navigators.

Table A.1
Research questions with response option

	Question	*Response options*
1	Is the bridge a place where you can calm down/quiet your mind or a place which requires an increased activity of senses?	1) The place I can calm down/quiet my mind 2) The place which requires an increased activity of senses 3) I do not pay attention to this
2	Have you ever experienced some pain in back, knees, shoulder, muscles during your watch on the bridge or immediately after?	1) Yes 2) No 3) I do not pay attention to this
3	Have you ever experienced some pain in head, eyes, neck, during your watch on the bridge or immediately after?	1) Yes 2) No 3) I do not pay attention to this
4	Do the bridges you have worked on meet your individual needs related to the comfort of work?	1) Yes 2) No
5	Which factor do you consider as the most disturbing in your work:	1) Pitching 2) Rolling 3) Surge 4) Vibrations caused by machinery 5) None of above
6	Do you feel that sometimes on the bridge it is too loud or sounds there are irritating (for example because of alarms or GMDSS communication)?	1) Yes both cases 2) Sometimes is too loud 3) Sounds are irritating sometimes 4) No
7	Do you have possibility to adjust temperature on the bridge subject to your needs and does it works correctly?	1) Yes 2) Yes, but the air conditioning is too strong (air is blowing too fast) 3) No 4) I don't know

Table A.1
(Continued)

	Question	*Response options*
8	Is the air on the bridge sometimes too dry or too humid?	1) Yes too dry 2) Yes too humid 3) Yes, both cases 4) No
9	Do you feel sometimes on the bridge the temperature difference between your feet level and head level?	1) Yes 2) No
10	Does your bridge have a room lighting in red color?	1) Yes 2) No 3) I am not sure
11	Can the conditions on the bridge increase the fatigue?	1) Yes 2) No 3) I am not sure
12	Did you know the definition of Ergonomics before?	1) Yes 2) No, this is the first time I have heard about it 3) I am not sure
13	Have you ever received training in Ergonomics on the navigation bridge?	1) Yes, at collage/University/courses 2) Yes, at my workplace 3) Yes, at my workplace and at collage/University/courses 4) No 5) I don't remember
14	In your opinion, for the best observation of the outside surroundings, the room should be:	1) Darker than outside 2) Brighter than outside 3) Just as bright as outside 4) It does not matter 5) I do not pay attention
15	Do you think that various ergonomic factors on the bridge have an impact on the effectiveness of your work and the safety of the ship?	1) Yes 2) No 3) I am not sure
16	Would you like to get to know more about Ergonomics and its influence on your work?	1) Yes 2) No
17	Do you think that adaptation of senses to current conditions on the bridge is necessary prior to taking over duties? (for Officers, Watchmen, Masters and Pilots)	1) Yes 2) No 3) I am not sure
18	Do you think that there is an overload of duties during the navigational watch and the duties like constant adjusting of brightness of devices or adjusting the volume/temperature are annoying/disturbing?	1) Yes 2) There is no overload, but this kind of duties are annoying/disturbing 3) No 4) I am not sure

Table A.1
(Continued)

	Question	*Response options*
19	Would adaptation of bridge to your individual ergonomics needs (having in mind eyes, posture, hearing health, etc.) have an impact for your loyalty & commitment to the company?	1) Yes 2) No 3) I have no opinion
20	In your opinion, do navigators comply with the ergonomic principles during navigational watch?	1) Yes 2) No 3) I have no opinion

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