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Maritime Usability Study by Analysing Eye Tracking Data

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The aim of the Integrated Navigation System (INS) on a ship bridge should be to provide the navigator with added value and aid in the complex task of conducting a safe and efficient passage at high speeds in demanding waters. This article presents a method for analysing eye tracking data to reveal sub-optimal design in the bridge layout and in the software graphical user interface on a maritime navigation display. The analysis of eye tracking data with a focus on scan path events indicates sub-optimal design, and the paper provides suggestions for improvement in design and interfaces. Pros and cons of using Eye Tracking Glasses in a maritime environment are presented. The importance of not affecting the normal behaviour of the navigator by collecting data is stressed, and how the software should provide good visualisation and interpretation of the eye tracking data.

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KEYWORDS

1. Eye Tracking. 2. Maritime usability study. 3. Navigation. 4. High Speed Craft.

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1. INTRODUCTION. Maritime ship bridges are becoming increasingly complex (Luraas, 2016), and Integrated Navigation Systems (INS) are being fitted on most new ships. The International Maritime Organization (IMO) recognises the need to "enhance the safety of navigation by providing integrated and augmented functions to avoid geographic, traffic and environmental hazards" (IMO, 2007, P.1). This provides the navigator with added value when it comes to planning, monitoring and controlling the safe progress of a ship. The information presented by the INS should be correct, timely and unambiguous. In addition, the design of the INS "should ease the workload of the bridge team and pilot in safely and effectively carrying out the navigation functions incorporated therein" (ibid., P.8).

With new technology aiding the Situational Awareness (SA) of the navigator, bridge layouts have evolved. On modern ship bridges information is presented on Multi-Function Displays (MFD), which consist of several applications that can be chosen based on what information is necessary for the navigator. The most common applications are the Electronic Chart and Display Information System (ECDIS), radar and conning displays, which are part of the INS. A variety of other MFDs may also present essential navigation information such as position, heading, speed, Automatic Identification System (AIS) information, wind data and more. The ship bridge has thus evolved from stand-alone analogue information with the use of paper charts to a digital display-based presentation of all relevant maritime information on MFDs.

A concern from both government institutions and industry is that this technological evolution actually decreases the SA of the navigator (Wingrove, 2016). There is also a concern that the navigator is addressing too much of his or her attention to digital displays (Norris, 2010; Hareide et al., 2016; MAIB, 2008).

This paper presents a usability study conducted on board the world's fastest littoral combat ships, the Royal Norwegian Navy corvettes. Collected eye tracking data is analysed with regards to the usability of the bridge layout and the Graphical User Interface (GUI) of the software incorporated in the INS. Eye tracking data is used and presented to conduct a usability study of the working environment of the navigator on the ship bridge. Eye tracking data is collected with two different types of Eye Tracking Glasses (ETGs). The advantages and challenges of collecting eye tracking data are presented together with a method for collecting, analysing and interpreting eye tracking data with regards to understanding usability. The objective of the research is to identify any specific issues with regards to usability in the bridge design and GUI in the working environment of the navigator.

1.1. *Previous Findings and Limitations.* In the maritime community there is not much research when it comes to understanding the navigator's visual perception, utilisation of this and time distribution with regard to Areas Of Interest (AOIs). The authors have written an earlier article presenting a comparative study of bridge and simulator navigation training (Hareide and Ostnes, 2016), with a follow up on understanding the visual perception and time distribution of the navigator (Hareide et al., 2016).

Limitations in the data set are related to the use of bridge navigation equipment on board the corvette which has been defined as AOIs for the navigator. This includes the ECDIS, radar, trip meter, controls (conning information) and the surroundings of the ship (outside). The data was collected during day time with a good visual detection range, and the use of radar is thus not representative. The data presented is collected from the navigator. Military navigation cannot rely on Global Navigation Satellite Systems (GNSS), and consists of traditional navigation techniques (Hareide, 2013, Appendix G). The data is collected on a high-speed craft with a length of 50 metres, and there could be deviations in this data when compared with that for larger and slower vessels.

There are more than 30 different ECDIS producers in the market today (ECDIS Limited, 2016), all with different GUIs. This study is undertaken on the Kongsberg ECDIS version 3.4.

2. BACKGROUND.

Eye tracking has shown to be promising in the analysis and development of a human-centred bridge design approach for an advanced Dynamic Positioning bridge (Bjørneseth et al., 2014), where eye tracking data has been used regarding a usability study of the Dynamic Positioning Operator (DPO) workstation. The use of eye tracking has also proven to be useful in differentiating the performance between expert and novice high speed navigators (Forsman et al., 2012). Analysing scan path events such as look-backs (revisits), indicates differences between experts and novices. A higher number of look-backs can indicate a larger degree of control and thus novice mistakes can be avoided (Rosengrant et al., 2009). Van Westrenen (1999) reported on the visual perception of pilots in Rotterdam and concludes that at times of high workload, up to 90% of the time is spent observing the surroundings of the ship (fairway in front of the ship), while Bjørneseth et al. (2014) reveal that the DPO spent an average of 35% of their time looking outside. The amount of time spent looking out of the window will be differentiated depending on the type of operation.

Several studies have also been conducted in other safety critical domains, such as power plant control rooms and aviation (Holmqvist et al., 2011). The effectiveness of using eye tracking data in a multi-model approach has also been outlined in usability evaluations of a ship's bridge (Papachristos et al., 2012). The car industry has used eye tracking data for optimisation of design and layout with good results (Chisholm et al., 2008).

Eye tracking is widely used for user interface design, and the purpose and usefulness of it is not much questioned (Bergstrom and Schall, 2014). If the goal of the usability evaluation is to assess if a user interface enables a human to conduct a specific task or operation, eye movements might provide a valuable insight into human behaviour. However, it should be noted that it might also provide limited information on evaluating whether a particular design facilitates task resolution (Groen and Noyes, 2010). Bergstrom and Schall (2014) point out some general considerations and drawbacks when it comes to using eye tracking in usability studies. They highlight that it is a time-consuming process, that it is an investment in both hardware and software, and that by purely using the equipment one could affect the techniques and user groups in a usability study.

There are several Original Equipment Manufacturers (OEMs) which produce different supportive equipment to be used in the conduct of safe navigation on board the ship bridge. The lack of standardisation of this equipment on the ship bridge has been pointed out as a concern (Meck et al., 2014). Kataria et al. (2015) points out the use of human-centred design and evolving it to crew-centred design as a solution in designing a better integrated navigation system. The International Organization for Standardisation (ISO) has published a standard on the "Human-centred design for interactive systems" (ISO 9241-210). This standard provides requirements and recommendations for human-centred design principles and activities, which outlines terms and definitions and the principles of human-centred design, and the importance of an iterative process in the plan and activities of designing for a human-centred system (ISO, 2010). There is also ongoing work with regards to standardisation with the initiative of drafting the Guideline for S-mode, which is scheduled for completion in 2019. The S-mode guidance aims to address matters not already mentioned in relevant IMO documents and to provide detailed requirements on presentation and the HMI (IMO, 2016).

Wiener (1989) introduced the term "clumsy automation" to describe automation that places additional and unevenly distributed workload, communication and coordination demands on pilots without adequate support. In short, clumsy automation is automation that makes easy tasks easier and hard tasks harder in challenging situations.

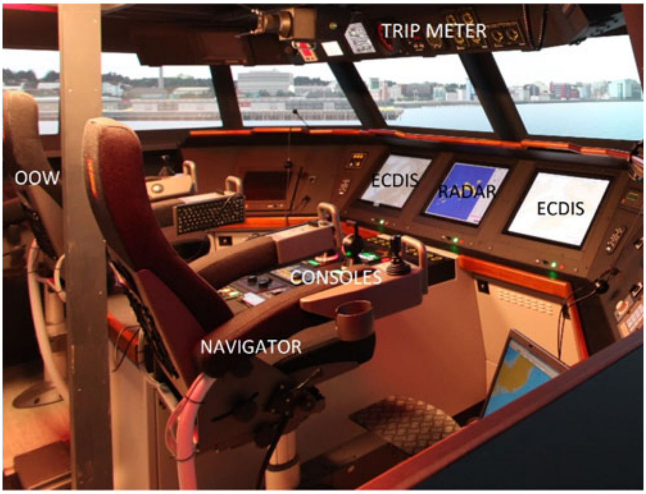

Figure 1. Corvette bridge layout.

3. EXPERIMENTAL DESIGN AND METHODS. Eye tracking data is valuable because it shows both conscious and unconscious processes of people looking at a specific area (Bergstrom and Schall, 2014).

3.1. *Study Design.* Collection of the data was undertaken on board the Royal Norwegian Navy corvettes. The corvettes' INS consists of radar, ECDIS, trip meter with navigation information and the consoles with conning information concerning the ship's propulsion and manoeuvring system. This is illustrated in Figure 1.

Based on the INS and the navigator's use of the different sub-systems, AOIs were identified in a pre-study (Hareide and Ostnes, 2016), and five areas of interest were identified:

1. Outside (AOI_O): Consists of the surroundings of the ships, and are defined by the boundaries of the windows on the ship's bridge.
2. ECDIS (AOI_E): The Electronic Chart and Display Information System (ECDIS) which is presented on the MFD in front of the navigator.
    a. Route Monitor (AOI_M) window is in the lower right corner of the ECDIS software.
3. Radar (AOI_R): The radar picture, presented on the centre MFD on the ship's bridge.
4. Trip meter (AOI_T): The Electromagnetic Log (EML) which presents speed and distance is located on a display above the navigator.
5. Consoles (AOI_R): Ship's propulsion control (water jets) and autopilot (AP).
6. White Space (AOI_W): The other areas than those defined by the AOIs.

The areas of interest are illustrated in Figure 1. The navigation team of the Corvettes consists of two persons, the Officer of the Watch (OOW) and the Navigator.

3.2. *Eye Tracking.* The eye tracking data was collected with two different sets of Eye Tracking Glasses (ETGs), as shown in Figures 2 and 3.

The two different technologies are compared in Table 1 (Tobii, 2016, SMI, 2016).

Figure 2. SMI ETG 2w (Photo courtesy SMI).

Figure 3. Tobii Glasses 2 (Photo courtesy Tobii AB).

Table 1. Comparison of Eye Tracking Glasses.

	SMI ETG 2w	Tobii Pro Glasses 2
Sampling rate	60 Hz/120 Hz	50 Hz/100 Hz
Field of View	60° horizontal, 46 vertical	82° horizontal/52 vertical
Calibration	1/3-point calibration	1 point calibration
Gaze tracking accuracy	0,5°	0,5°
Gaze tracking range	80° horizontal, 60° vertical	>160° horizontal, 70° vertical
Scene camera resolution	Resolution:1280x960p@24 fps 960x720p @30 fps	1920 × 1080 at 25 fps
Frame dimension (WxH)	173 mm × 58 mm	179 mm × 57 mm
Weight	47 g	45 g
Interchangeable nose piece	Yes (3)	Yes (3)

3.2.1. *Eye Tracking Data Collected With Tobii Pro Glasses 2.* The dataset collected with the Tobii Pro Glasses 2 (Tobii, 2016) was collected on board one of The Royal Norwegian Navy corvettes in spring 2016, and the outside surroundings and weather conditions correspond to those collected with the SMI 2W ETGs (SMI, 2016; Hareide and Ostnes, 2016).

A precondition for interpreting the two datasets is that the outside surroundings and weather conditions are similar.

3.3. *Eye Tracking Metrics And Data.* "Fixation" is defined as the state when the eye remains still over a period of time on a specific point (Holmqvist et al., 2011), and in this data set the period is given as more than 80 milliseconds (ms). Fixation time is the time period of a specific fixation. "Saccade" is defined as the rapid eye motion between two

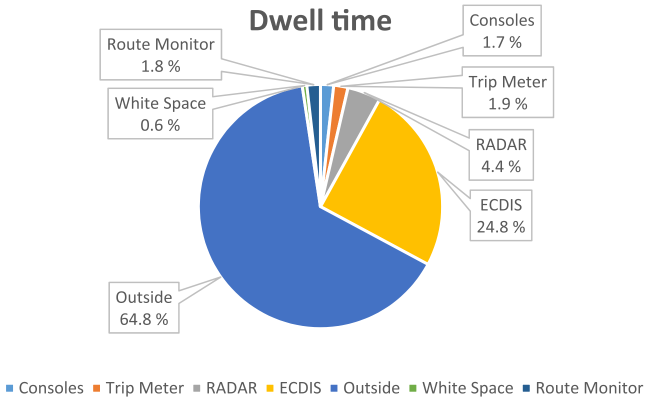

Figure 4. Dwell time in the AOIs.

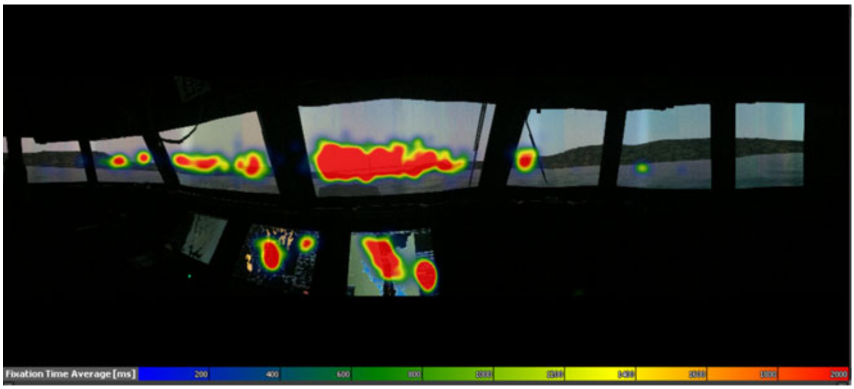

Figure 5. Heat Map of Eye Tracking data.

fixations, understood as from one fixation to another (ibid.). A "Dwell" is defined as a visit in an AOI, from entry to exit (ibid.) The "dwell time" is defined as the total amount of time spent in the specific AOI. The dwell time in each of the AOIs from the eye tracking dataset is presented in Figure 4.

"White space" is all the area not defined by the AOIs in Figure 1 where the participant's eye movements are recorded. Dwell time in all the above AOIs and white space should sum up to 100%, but there could be a 10–13% deficit due to eye tracking data loss. The reason for this loss could be blinking, eye position outside the tracking range of the eye tracker and connection losses in the device.

"Attention maps" are visualisations and representations of the eye tracking data, and could also be defined as the presentation of spatial distribution of eye-movement data. Examples of attention maps are heat maps or focus maps. These attention maps are generated by the eye tracking software. Heat maps show area with many fixations or data samples highlighted with warm colours (red) and regions with less data are marked with colder colours (blue), see Figure 5. The bridge layout is presented in Section 3.1 and can be compared with Figure 1.

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Figure 6. Focus Map of Eye Tracking data.

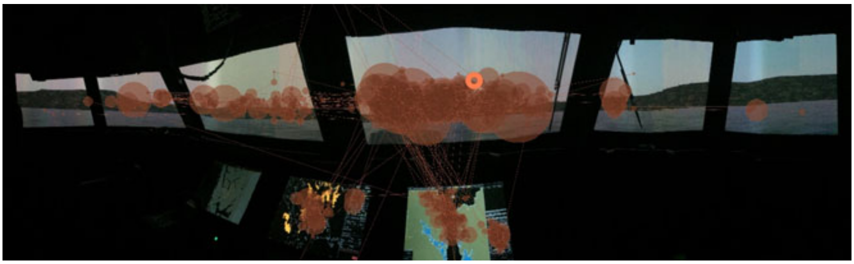

Figure 7. Scan Path presentation of the collected Eye Tracking data.

Focus maps are similar, but they present areas with few or no fixations as blind zones, see Figure 6.

"Scan path" is defined as the route of oculomotor events through space within a certain timespan (Holmqvist et al., 2011). A fixation is shown as a circle, the size of which defines the period of the given fixation. The lines between the fixations represent a saccade. This is shown in Figure 7.

A "sequence chart" is a representation of the AOIs over time. The sequence chart shows the order and duration of dwells in the AOIs, and is shown in Figure 8 (ibid.).

"Look-backs" are operationalised as saccades to AOIs already looked at, and are also known as returns and refixation. Look-backs are closely related to "inhibition of return" which is the observation that attention is unlikely to be re-directed to previously inspected areas (ibid.). A look-back could constitute a failure of memory (Gilchrist and Harvey, 2000), but one must also account for the fact that working memory has a limited temporal capacity. When using look-backs one must define how long ago the AOI was previously looked at for fixations there to count as a look-back, which is typically 10 seconds. In web-page interaction interpretation of the number of times a user looks at a link before clicking it, this represents confusion concerning the purpose of that link. The user looks back at the link (revisits) several times to make sure it is the correct link for their task (Bergstrom and Schall, 2014). Look-backs can also indicate that the user is rechecking the information in the given area, and could be interpreted as importance of information in the given area (Mitzner et al., 2010). Whether and when looking at how often a participant is looking back/rechecking the content they were seeking in a given AOI could imply a difficulty in

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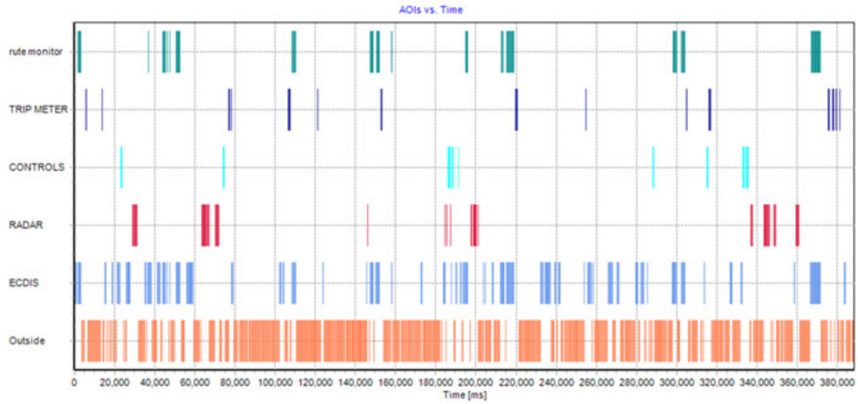

Figure 8. AOI Sequence Chart from Eye Tracking data from SMI software.

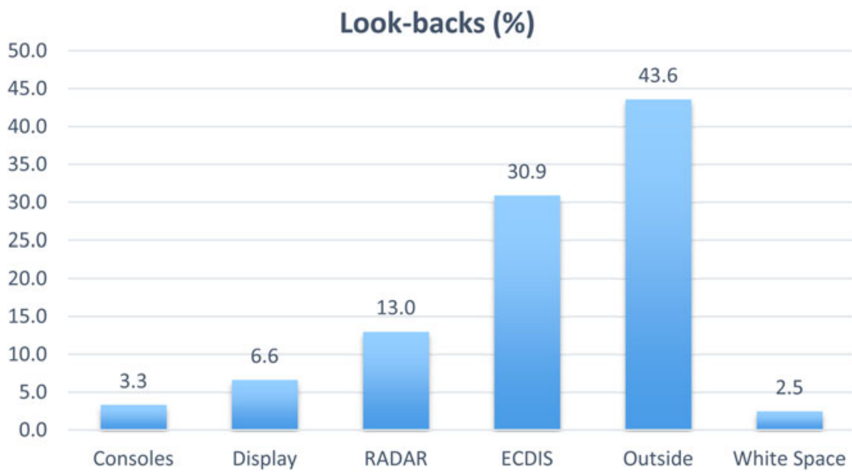

Figure 9. Look-backs in percentage in AOIs.

understanding its content or a specific user attraction to the AOI (Bergstrom and Schall, 2014). The number of returns could also indicate a semantically informative area, which aligns to the number of dwells (Holmqvist et al., 2011). In a complex environment like the maritime bridge, the look-back or return/refixation will indicate the importance of the AOI. The look-backs for the eye tracking data collected in this study are presented in Figure 9.

A "Backtrack" is the specific relationship between two subsequent saccades where the second goes in the opposite direction to the first (Holmqvist et al., 2011). It is also known as a regressive saccade which is rapid eye movements that are backtracked so that a user looks back at content previously seen. This behaviour can be indicative of confusion or uncertainty (Bergstrom and Schall, 2014). Holmqvist et al. (2011) point out that backtracks are notoriously ambiguous events, and must be related to other scan path events or eye tracking data when analysed.

For usability studies, one could argue that the use of backtracks is a better representation due to changes in goals and an indication of a mismatch between the users' expectation

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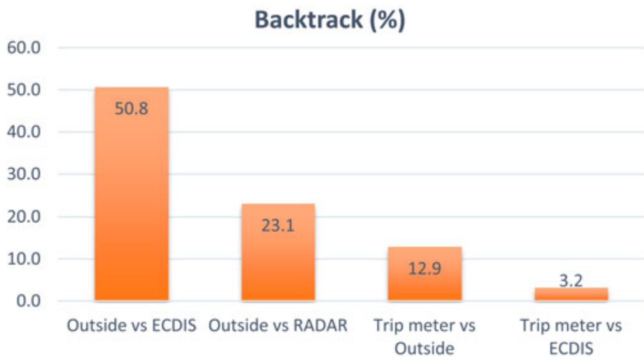

Figure 10. Backtracks in percentage between four AOIs.

and the interface layout (Goldberg and Kotval, 1999). With the AOIs defined in this study (Figure 1), a backtrack will be interpreted as an eye movement from a specific AOI to another, and back to the specific AOI. This can indicate that the navigator finds it challenging to interpret the information in that AOI, and thus needs to backtrack to the AOI to validate the assumption. The number of backtracks in Figure 10 is given in percentages to identify the relative relationship between the different backtracks. More than 50% of the backtracks are concerning outside and the ECDIS, which could represent a challenge for the navigator to interpret or understand and to memorise the information given from the ECDIS.

3.4. *Methods.* In order to conduct a study to identify usability issues in the bridge layout and in the GUI, the following methods were selected:

1. Analysis of ocular behaviour (visual perception).
    a. Dwell time.
    b. Attention maps.
    c. Sequence charts.
2. Analysis of scan path events.
    a. Look-backs.
    b. Backtracks.
3. Identify sub-optimal design and GUI solutions in the working environment of the navigator.
    a. Present a possible solution to compensate for the sub-optimal design.

This should be conducted as an iterative process in accordance with the principles in ISO 9241-210.

4. FINDINGS. In the findings three interesting observations are presented from the eye tracking data regarding the bridge layout and software GUI together with the pros and cons with the use of eye tracking data in maritime usability studies.

4.1. *Maritime Usability Study Of Bridge Design And Software GUI With Eye Tracking Data.* To understand how the bridge is laid out, it is important to understand the context of use. The context of use is defined as "hardware, software and materials, and the physical and social environments in which a product is used" (ISO, 2010). The corvettes

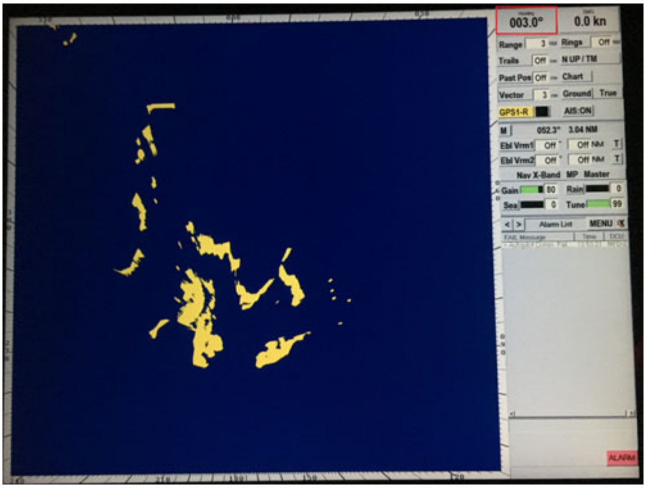

Figure 11. Radar GUI, heading information in upper right corner.

are warships, and their use in navigation is outlined in earlier work (Hareide and Ostnes, 2016).

4.1.1. *Heading Repeater.* When analysing AOI Radar (AOI_R), an interesting observation is made in the attention maps in Figures 5, 6 and 7. All the attention maps indicate an extra attention drawn to the upper right corner of the AOI_R. Looking at the GUI of AOI_R, the upper right corner is presenting the current heading and speed, shown in Figure 11.

Comparing dwell time and look-back in Figures 2 and 9 for AOI_R, there is a ratio of 4·4 in advantage of look-backs compared with dwells for AOI_R. 23·1% of all backtracks (Figure 10) were conducted to AOI_R, indicating difficulty in interpreting the information. To understand if this is due to difficulties in understanding or interpreting the AOI, or if it is due to rechecking, the context of use has to be known. The context of use in AOI_R is during the turn and control phase of the navigation, when the navigator conducts the turn as a helmsman and controls the heading of the vessel. This is done by the navigator after every turn, and the frequency is high when navigating at high speeds in littoral waters. The navigator compares the planned course with the current heading, and assesses whether the ship is in the correct and expected position. This is an important control mechanism for high speed navigators in littoral waters, and it is thus essential that the heading is easily available for the navigator. Based on the number of look-backs and backtracks, the context of use does not explain the high numbers even though one should expect a high number of look-backs due to the frequency of turns. The eye tracking data have revealed a challenge for the navigator to understand and interpret heading information, which is compensated by revisiting (look-back) and backtracking to the AOI to avoid a misunderstanding.

To better provide heading information for the navigator, a more accessible heading repeater should be integrated in the navigation system.

4.1.2. *Trip Meter Layout.* The context of use of AOI_T is as a distance measurement tool for the navigator. When conducting a turn, the navigator should plan and conduct the turn with more than one turning indication, known as primary and secondary turning indication. This could be the trip meter and a visual bearing. The navigator uses the trip meter on each leg to verify the distance before starting on a new leg, which is known as

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Figure 12. HMI Electromagnetic Log.

a primary or secondary turning indicator. The Electromagnetic Log (EML) could also be used in position fixing by the means of bearing calculations known as a four-point bearing (Hareide, 2013, Appendix G).

Figure 4 shows AOI_T consuming 1·9% of the navigator's visual attention. Analysing backtracks in Figure 10 shows that 12·9% of the backtracks are between AOI_T and AOI_O, and this could indicate poor usability. Looking at the ratio of look-backs compared with the dwell time, the ratio is 5·2. This ratio also indicates either confusion or double checking from the navigator.

The attention maps and the sequence chart also indicate that the AOI_T is drawing navigators' attention.

The physical placement of AOI_T is above the navigator shown in Figure 1. The navigator interacts with the display by reading out the values of the trip counter and by resetting the trip counter. This is shown in Figure 12.

The EML display is designed with six soft key buttons, which have the same size and shape, on a line at the bottom of the display. One of the buttons is used for resetting the trip meter. Both during daytime and especially during night time it is difficult for the navigator to select the correct button without giving the AOI_T visual attention. The procedure of resetting the trip meter is safety critical as it has a function as a primary or secondary turn indicator, the navigator puts extra effort into doing this task. To be sure that the trip meter is reset, the navigator changes their focus and shifts the head position to monitor that the trip meter is reset. In addition, the button needs to be pressed for 2 seconds in order to reset it, which further hampers the procedure.

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From the eye tracking metrics of look-backs and backtracks, together with an understanding of the context of use, it is shown that the navigator must double check AOI_T. The scan path events of backtracks and look-backs has identified poor usability and sub-optimal bridge design. A possible solution for this challenge is a reset button and read out display for the trip meter which is more available and efficient for the navigator.

4.1.3. *Usability Study of Software GUI.* The dwell time could represent the importance of an AOI (Jacob and Karn, 2003). In the challenging environment of high speed navigation in littoral waters, the main focus of the navigator must be in the surroundings of the ship. This is supported by navigation techniques, such as the Dynamic Navigation (DYNAV) concept (Forsman et al., 2012). Related to the eye tracking data, most of the navigator's attention should be in AOI_O. Dwell time identifies which AOIs the navigator spends the most time focusing on. 24·8% of the navigator's attention is drawn to the ECDIS, making it the largest contributor for visual attention drawn away from the outside of the ship.

When analysing look-backs in Figure 8 compared with dwell time in Figure 3, it is identified that the navigator revisits the AOI_E more than the AOI_O with a ratio of 1·9. This ratio could indicate a difficulty in interpreting information in AOI_E, or simply a need for the navigator to verify the information. This double-checking could also be an indication of problems with collecting the relevant information from the ECDIS GUI. One could also argue that the ratio of 1·9 is not significant compared to the ratios from AOI_R and AOI_T. Analysis of backtracks in Figure 9 reveal that more than 50% of all backtracks are between AOI_O and AOI_E, which could indicate a challenge in the usability of the ECDIS GUI. Backtracks must be used with care due to the ambiguity of the event, but used together with other scan path events or eye tracking data provides accumulated information pointing towards a GUI usability challenge.

For further analysis of the AOI_E, we use the scan pattern in Figure 6. Most of the attention is drawn towards the chart, but it is also identified that the navigator's attention is attracted to the lower right corner of the AOI_E GUI. Usability studies should be an iterative process, and based on this finding, a need for redefining the AOI is identified and conducted as shown in Figure 14.

Redefining the AOI identifies the new AOI Route Monitor (AOI_M) window. The purpose of the Route Monitor window is to present the position of the ships against the planned route for the navigator. When looking at the dwell time in Figure 3, it is identified that the navigator spends 1·8% of the time interpreting the data from this AOI. $AOI_M$is attracting the navigator's attention shown by the visual distribution of time in the sequence chart in Figure 7.

The navigator's context of use of the route monitor window is to collect information regarding turning information (1), heading mark information (1), time to Wheel-Over-Point (WOP) (2), course information (3), distance on leg information (4) and cross-track distance (5) which is the shortest distance between the own-ship and the intended route. This is shown in Figure 14. This information is also incorporated in a voice procedure in the navigation team.

The Route Monitor Window is in the bottom right corner of the ECDIS GUI, and is at a distance of approximately 2 metres from the navigator. The numbers and letters are too small for the navigator to read, and the navigator must use extra attention and focus on interpreting these data. The large number of backtracks also indicates a challenge in usability in the AOI, and a redesign of the GUI should be considered. A better GUI with

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Figure 13. Redefining AOIs with AOI Route Monitor.

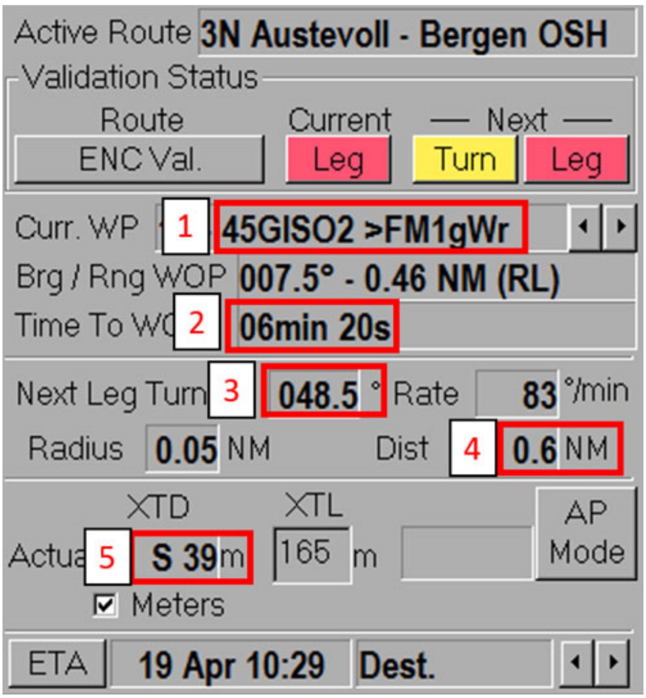

Figure 14. Content of the Route Monitor window.

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Figure 15. Glare in ETGs.

regards to presentation of relevant information to the navigator would reduce the effort and time for the navigator in collecting this vital information for the voyage.

4.2. *Maritime Usability Study with the use of ETGs.* It is important not to disturb the techniques and behaviour of the user group when collecting eye tracking data with ETGs. A challenge was identified with regard to loss of data due to the participants looking outside the frame dimension. This is caused by the navigator looking over or under the glasses; mostly under due to the angles from the operator to the screens. The physical reasons for this is the size of the frame where the eye movements are collected, in addition to the distance from the eye to the lenses. Figures 2 and 3 show a difference in the thickness of the frames, which could influence the navigator. If the distance is too long, there is a higher risk of the participant looking under the glasses. This can also be adjusted by the different nose pieces that come with the ETG, but they are primarily used to conduct a calibration of the equipment before starting the recording and should not be changed. The producers suggested setting up a physical barrier so that the participant did not look outside the frame of the ETG, but this was not conducted as it was considered to affect the natural behaviour of the navigator.

The use of ETGs together with binoculars is challenging, especially for those who are not accustomed to wearing glasses. The use of binoculars is safety-critical in high speed operations in littoral waters, and the subject has to be trained and comfortable with using ETGs together with binoculars before collection of the dataset to prevent interruptions in the data collection.

When using the ETGs in twilight, the light pollution from the scene cameras is distressing for the navigator. During dusk the binoculars are frequently used to identify objects during the passage. The light pollution in addition to the challenges with the use of binoculars makes the use of current generation ETGs impossible in twilight and during night time.

When using the ETGs during daytime, particularly when the sun is close to the horizon, a glare in the ETGs occurs which is shown in Figure 15. This is disruptive for the navigator, and makes the use of ETGs a challenge.

Collecting eye tracking data, especially in a field study in a dynamic environment such as on board the Norwegian corvettes, is challenging with limited battery capacity and the use of cables for ETG connection and charging. This can be mitigated with the use of power banks and wireless connections, but must be accounted for in the design of the study.

When collecting data in a dynamic environment on board a ship, it is important that the calibration process is simple, accurate and quick. The calibration process can be challenging if there is a considerable contrast in the brightness of the light between the environment and the background of the calibration. This is often the case on board a ship where the bridge is more dimmed than the outside during daytime. This could result in lost calibration, and thus extra post-process work which also could make some of the data ambiguous.

The software presentation concerning visual presentation of the attention maps is important to better understand and analyse the eye tracking data. The use of a sequence chart, shown in Figure 8, is an important feature which not all producers provide. The sequence chart is a good visualisation of time-stealing displays and areas when optimising the design of the bridge layout and software GUI on an integrated navigation system.

When using automatic eye tracking data processing, there are indications that this process is not thorough and can be considered as not fully developed. The manual work of analysing eye tracking data is a time-consuming job, where approximately 60 minutes of processing goes into every 10 minutes of recorded eye tracking data. When the automatic eye tracking data processing function is fully developed, this will make the use of eye tracking data more accessible.

5. CONCLUSION.

Work as a navigator on a high speed craft is a demanding job, and in the past few years several new displays and technologies have been introduced to aid and provide added value for the navigator. When introducing new technology to the navigator, it is important to make a good interface in accordance with the human-centred design concept. The design of the bridge must facilitate the attention of the navigator to the surroundings of the ship for continuous control and monitoring of the safe passage of the ship.

This article shows how eye tracking data, with a defined method utilising scan path events and attention maps, can be used to identify which areas of interest attract the navigator the most. The data set presents an example of sub-optimal bridge layout concerning placement of equipment, together with two examples of sub-optimal GUI in radar and ECDIS software. The eye tracking data identifies areas of interest which draw too much of the visual attention of the navigator, and we have presented suggestions for improvements in the bridge layout and software GUI based on the findings. Eye tracking data shows good potential for analysing the usability of a bridge layout and software GUI on a ship bridge when using the correct methods.

Some advantages and challenges with using ETGs are laid down, with emphasis on the importance of not affecting the normal behaviour of the navigator by collecting data, and also how the software should provide good visualisation and interpretation of the eye tracking data.

Further work includes implementing the current findings on board with development and optimisation of software GUI and bridge layout, contextualising and developing a recommended navigator scanning pattern when conducting navigation on an integrated navigation system and concept and development of a graphical user interface for presentation of relevant information to the navigator.

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ETHICAL STANDARDS

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Consent forms were used in all data collection.

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