



CHALMERS



Expert versus Novice mariners, a study using eye-tracking in an unfamiliar ship handling simulation scenario

Bachelor thesis for Master Mariner Program

**GABRIELLA PRINTZ
EMIL SVARTENGREN**

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2023

Expert versus Novice mariners, a study using eye-tracking in an unfamiliar ship handling simulation scenario

Bachelor thesis for Master Mariner Program

GABRIELLA PRINTZ
EMIL SVARTENGREN

Department of Mechanics and Maritime Sciences
Division for Maritime Studies
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2023

Expert versus Novice mariners, a study using eye-tracking in an unfamiliar ship handling simulation scenario

GABRIELLA PRINTZ
EMIL SVARTENGREN

© GABRIELLA PRINTZ, 2023
© EMIL SVARTENGREN, 2023

Department of Mechanics and Maritime Sciences
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover:
Photo of the bridge in Chalmer's Full Mission Bridge Simulator. Photo by Emil Svartengren.

Department of Mechanics and Maritime Sciences
Chalmers University of Technology
Göteborg, Sweden 2023

PREFACE

This bachelor thesis is a comparison of Expert and Novice mariners, using eye-tracking technology at Chalmers University of Technology, Department of Mechanics and Maritime sciences. The Master Mariners program is a four-year program at Chalmers and this thesis is part of a course that will span from 31/10 - 2022 to 15/3 - 2023. The thesis is based on a study currently being conducted by the Swedish Maritime Administration, studying the gaze patterns of Swedish maritime pilots to see if the eye-tracking technology can be used for analyzing purposes of the pilot education.

We would like to give a special thanks to our supervisor Reto Weber, for giving us guidance and insight when it came to both writing and working with the simulator.

We would also like to thank Andreas Edvall, Anders Johanneson, and Daniel Boström from the Swedish Maritime Administration for providing us with the equipment, inspiration and technical support.

Finally, we would like to thank the participants for helping us gather data.

Expert versus Novice mariners, a study using eye-tracking in an unfamiliar ship handling simulation scenario

GABRIELLA PRINTZ
EMIL SVARTENGREN

Department of Mechanics and Maritime Sciences
Chalmers University of Technology

SAMMANDRAG (in Swedish)

Eye-tracking-teknik är ett område som har stor potential för att upptäcka skillnader och beteenden hos människor i många branscher. En av dessa branscher är den maritima industrin. Denna studie kommer att försöka hitta skillnader i blickaktivitet mellan 4:e års sjökaptens studenter och lotsar. För att motivera introduktionen av ny teknik i exempelvis utbildning är det först viktigt att se om det finns skillnader som kan bidra till att utveckla nya sätt att överföra kunskap.

Arbetet som presenteras har gjorts på Chalmers tekniska högskola där fartygshanteringssimuleringar utfördes av två provgrupper som var utrustade med eye-tracking-glasögon för att hitta skillnader. Dessutom fylldes ett frågeformulär i av deltagarna för att se skillnaderna mellan vad de upplevde att de fokuserade på, kontra vad de faktiskt fokuserade på. Spåren från simuleringskörningarna sparades och presenterades för att se skillnader i tillvägagångssätt för navigering mellan grupperna.

Resultatet av studien visar att experter fördelade sin blickaktivitet mer mellan instrument och visuella observationer än nybörjare. Nybörjare fokuserade mest på sina conning skärmar och direkt framför fartyget. Om vi tittar på spåren kan vi se en stor skillnad i tillvägagångssätt av navigering. Resultaten som hittats visar att flera skillnader mellan gruppernas blickaktivitet kan vara intressanta att utforska vidare såsom användningen av navigationsutrustningen. Detta kan också ses i enkätsvaren, eftersom båda grupperna hade liknande svar för vad de uppfattade ha fokuserat på men valde att svara med olika formuleringar som tydde på att de möjligtvis använde utrustningen för olika ändamål. Spåren visar en tydlig skillnad i tillvägagångssätt och experter var mycket mer konsekventa i hur de utförde varje körning.

Även om resultaten visar oss stora skillnader mellan grupperna, gör avgränsningar av denna studie att dessa resultat inte kan generaliseras för mycket då antalet deltagare var lågt och endast inkluderade mycket specifik demografi.

Nyckelord: eye-tracking, novice vs expert, maritime pilots, heat maps

Expert versus Novice mariners, a study using eye-tracking in an unfamiliar ship handling simulation scenario

GABRIELLA PRINTZ
EMIL SVARTENGREN

Department of Mechanics and Maritime Sciences
Chalmers University of Technology

ABSTRACT

Eye-tracking technology is an area that has a lot of potential in discovering differences and behaviors of people in many industries. One of these is the maritime industry. This study will try to find differences in gaze activity between 4th-year Master Mariner students and maritime pilots. To justify the incorporation of new technology in, for example, education, it is first important to see if there are differences to be found that can help develop new ways of transferring knowledge.

The work presented was done at Chalmers University of Technology, where ship handling simulations were executed by two sample groups that were equipped with eye-tracking glasses to find differences. Additionally, a questionnaire was filled out by the participants to see the differences between what they perceived they focused on versus what they actually focused on. Tracks from the simulation runs were saved and presented to see a difference in the approach of navigation between the groups.

The result of the study shows that experts divided their gaze activity more between instruments and visual observations than novices. Novices were mostly focusing on their conning screens and straight ahead of the ship. When comparing the tracks, a large difference can be seen in the approaches. Results found show that multiple differences between the groups' gaze activity could be interesting to explore further such as the use of the navigational equipment. This can also be seen in the questionnaire responses, as both groups had similar answers for what they perceived to have focused on but chose to answer with different wording, suggesting they may have used the equipment for different purposes. Tracks show a distinct difference in approach execution and experts were a lot more consistent in how they performed each run.

Although the results show us big differences between the groups, delimitations of this study mean that these results cannot be generalized as the number of participants was low and only included specific demographics.

Keywords: eye-tracking, novice vs expert, maritime pilots, heat maps

TABLE OF CONTENTS

1. Introduction	1
1.1 Background	1
1.2 Aim of the Study	2
1.3 Research Questions	2
1.4 Delimitations	2
2. Theory	3
2.1 Educational Background of Participants	3
2.2 Eye-tracking	3
2.3 Previous Eye-tracking Studies	5
2.4 Maritime Eye-tracking Studies.....	5
3. Methodology	7
3.1 Demographics.....	7
3.2 Ethics.....	7
3.3 Technical Setup	7
3.4 Experimental Setup	10
3.4.1 Trial Runs.....	10
3.4.2 Briefing	10
3.4.3 Participants' Setup of the Bridge	10
3.5 Data Collection.....	10
3.5.1 Questionnaire	10
3.5.2 Eye-tracking Recordings.....	11
3.5.3 Simulator Tracks	11
3.6 Data Analysis	11
3.6.1 Heat Map Analysis.....	11
3.6.2 Heat Map Analysis of Participants	12
3.6.3 Questionnaire Analysis	13
3.6.4 Analysis of Tracks	13
4. Results	14
4.1 Passing the Fishing Vessel	14
4.2 Fairway Approach	15
4.3 Passing the Piers.....	16
4.4 Harbor Basin	17
4.5 Questionnaire Results.....	17
4.6 Tracks	20
5. Discussion	21
5.1 Method Discussion.....	21

5.1.1 Mixed Methods Discussion.....	21
5.1.2 Demographics Discussion.....	21
5.1.3 Experimental Setup Discussion	21
5.1.4 Technical Setup Discussion	21
5.1.5 Analysis Discussion	21
5.2 Heat Map Differences Between Experts and Novices	22
5.2.1. Passing the Fishing Vessel.....	23
5.2.2 Fairway Approach.....	23
5.2.3 Passing the Piers	23
5.2.4 Harbor Basin	24
5.3 Participants' Perception Compared to Heat Maps	24
5.4 Comparing the Tracks Between Experts and Novices	24
6. Conclusion.....	26
6.1 Recommendations for Further Research	26
References	27
Appendix	27

LIST OF FIGURES

Figure 1 Example of a Heat Map 4
Figure 2 Example of Gaze plots 4
Figure 3 Bridge Setup..... 8
Figure 4 Scenario Overview 9
Figure 5 Map of snapshot sections 12
Figure 6 Heat maps Snapshot 1 14
Figure 7 Heat maps Snapshot 2 15
Figure 8 Heat maps Snapshot 3 16
Figure 9 Heat maps Snapshot 4 17
Figure 10 How difficult did the participants find the scenario? 18
Figure 11 Where did the participants perceive they were looking/focusing the most during the simulation? 19
Figure 12 Tracks of the scenario runs 20

LIST OF TABLES

Table 1 Ship data 10

ACRONYMS AND TERMINOLOGY

CoC	Certificate of Competency
COLREG	International Regulations for Preventing Collisions at Sea
Conning	Screen on a bridge with information, including the rate of turn, rudder angle, various speeds, courses, pitch, and bow thruster.
ECDIS	Electronic Chart and Display Information System
FMBS	Full Mission Bridge Simulator
Gaze Plot	Image showing pattern and order where one or multiple people have looked.
Heat Map	Image showing where one or multiple people have looked, where a warmer color shows longer time spent.
IMPA	International Maritime Pilot Association
SMA	The Swedish Maritime Administration
Snapshot	Reference images to map eye movements to create heat maps and gaze plots.
ROT	Rate of Turn

1. INTRODUCTION

The maritime industry is a field where it is estimated that over 80% of accidents are caused by the human element (Martinez-Marquez et al., 2021). In recent years, the term "human element" has taken on a new meaning which involves identifying the underlying causes in the system, rather than putting the blame on the individual (le Coze, 2022). A way to identify what the causes could be is to use eye-tracking (Duchowski, 2017). As a person's eye movements are closely linked to their thoughts, examining these movements can reveal whether any crucial areas of interest have been overlooked (Carter & Luke, 2020). Additionally, eye-tracking can serve as a tool for observing decision-making processes, providing insight into whether decisions were made based on visual cues (Hetherington et al., 2006; Martinez-Marquez et al., 2021). By knowing and understanding the underlying causes, preventative measures can be taken to reduce the risks in the future (Duchowski, 2017).

Multiple studies state that conducting studies using eye-tracking technology is a valuable endeavor that can provide insight into both education and how people perceive different scenarios (Atik & Arslan, 2019; Carter & Luke, 2020; Eklund et al., 2020; Martinez-Marquez et al., 2021). This study will focus on the insight into how different groups of people perceive a ship-handling scenario using eye-tracking. In some of the studies referenced, experts being more proficient than novices is a reoccurring theme (Capogna et al., 2020; Dzung et al., 2016; Kasarskis et al., 2001; Xiong et al., 2016). Differences in eye movements could be found that would not have been possible without the use of eye-tracking. Although this study will not focus on answering any questions regarding education, an argument could be made that the results may provide some insights for future studies of eye-tracking in education.

Finding differences this way may provide further reasons to expand the use of said technology that may lead to more future studies and research on the subject. In a study by Xiong et al. (2016) on aviation pilots, it was discovered that experts had shorter fixation times with more fixation points, a faster scan of the cockpit, and overall better results in their simulated landing runs. Using these patterns of sweeping for information from the experts, two different control groups of cadets were used, where one got instructions from the experts' sweep patterns and the other group did not, and the instructed group had a higher performance rate (Xiong et al., 2016).

Eye-tracking technology is becoming increasingly more common in many different industries such as Maritime, Aviation, and Construction to name a few (Martinez-Marquez et al., 2021), where the consequences of making a mistake can be devastating in both an economic and environmental sense but also potentially at the cost of lives. Considering this, it is in the industry's best interest to reduce these risks as much as possible by any means necessary. Using eye-tracking to gain more knowledge about when, where, and how long people direct their attention to specific points can be very valuable (Atik & Arslan, 2019; Capogna et al., 2020; Carter & Luke, 2020; Eklund et al., 2020; Martinez-Marquez et al., 2021).

1.1 Background

The Swedish Maritime Administration (SMA) are conducting an eye-tracking study to see if the technology could be used to train upcoming pilots by having them watch previous

recordings and letting instructors observe. Their study is set to be published in the summer of 2023.

Eklund et al. (2020) did a pre-study about how eye-tracking could be used as a tool to transfer knowledge between maritime pilots and students. However, to transfer knowledge between the groups, a difference must be established. This in turn raised the question if 4th-year Master Mariner students and maritime pilots would focus on different points during ship handling and potentially what those differences could be.

1.2 Aim of the Study

Using eye-tracking, this study aims to investigate if there are any differences between experts and novices regarding:

- Key points of eye focus during a simulated port approach.
- Perception of participants, what they think they focus on compared to what they focus on in reality.
- Execution of the simulated port approach.

1.3 Research Questions

Are there any differences between the expert and novice groups that can be seen in heat maps from simulator scenarios?

Do participants' own perceptions of where they direct their attention the most match up with what they focus on during the simulation?

Are there any differences between the experts and novices in the execution of the port approach in the simulator?

1.4 Delimitations

The scenario in this study only focuses on navigating one specific ship into one specific port alone and does not include COLREG situations, communication, or bridge resource management.

Tobii Pro Glasses 3 and Tobii Pro Lab can create both heat maps and gaze plots. However, only heat maps are used in this study due to the limited time and the fact that heat maps present a well enough picture to answer the research questions.

The mapping between the simulation recordings and the photos used as references, the snapshots, were slightly off. In the produced heat maps on top of the snapshots, a lot of activity is shown on the deck of the ship rather than ahead of it. However, the recordings show that the focus lay ahead of the ship. The manufacturer was contacted, but no clear explanation has been provided as to why this happened. Another issue that is prevalent in eye-tracking studies was the fact that the glasses, unfortunately, did not work with prescription glasses and therefore had an impact on some of the participants.

All participants from the novice group are Swedish students and all experts are Swedish maritime pilots. Therefore, the results cannot be generalized for the entire maritime industry.

2. THEORY

2.1 Educational Background of Participants

In Sweden, the Master Mariner education is a 4-year long program with both theoretical and practical elements, including spending a year at sea (Chalmers, 2023). Successful completion leads to a Certificate of Competency (CoC) to work as a 2nd officer on ships of unlimited size and with further sea service acquire the CoC as Chief Officer and Master. By the 4th year, the students have spent 8-10 months at sea gaining experience with maintenance, navigation, and other officer duties. Besides the time spent at sea, there are several courses about navigation that also have simulations teaching the students about ship handling.

A maritime pilot is an expert in ship handling and is trained in navigation in specific areas (International Maritime Pilots' Association [IMPA], n.d.). The pilot is responsible for the pilotage of vessels and shall give and oversee the orders to ensure safe navigation and maneuvering. This is done with consideration of the environment and the safety at sea. The captain of the vessel is still held responsible for the vessel and its voyage during pilotage (Sveriges Riksdag, 2008).

In Sweden, to become a pilot, a Master Mariner CoC and experience serving as captain or senior officer is required. The Swedish Maritime Administration (SMA) select pilot candidates through psychological aptitude tests and ship handling simulator tests. They will then get training at their local pilot station, leading up to their first pilot license for smaller vessels. With further experience, it will lead to an unlimited pilot license which allows pilotage of ships of any size (Swedish Maritime Administration [SMA], 2022).

2.2 Eye-tracking

The idea that eye movement and where a person looks are related was described in 1823 by Charles Bell where the author talks about how the cornea moves under the eyelid when following an object with one eye open and how the eyes behave when unconscious (Bell, 1823). The first method of measuring eye movements came in 1898 when Delabarre attached a plaster with a tiny hole onto the eyeball for the pupil to record them. (Delabarre, 1898) Other methods throughout history have included using prisms to reflect a beam of light on a film with the help of corneal movements in 1935 and a corneal lens in 1967 to measure perception (Carter & Luke, 2020).

Today, eye-tracking measuring is easier to use for both the researcher and the participant. Nowadays, most devices measure eye movements with both cameras and a light source which is usually an infrared one that the human eye cannot see. One method is using a wearable eye tracker like a pair of glasses which allows the participant to move around in an area. The other means is to use a mounted eye tracker where the participant cannot move, but it will give a more accurate result (Carter & Luke, 2020).

Two common ways to use eye-tracking software as an analytic method are to produce heat maps and gaze plots. A heat map (Figure 1) is an image that the subject has looked at and a representation of the duration that the person has looked at a specific location. A gaze plot (Figure 2) shows the order of eye movements the subject has undergone (Hareide & Ostnes, 2017).

Figure 1
Example of a Heat Map



Note. The colors show where the focus of the eye has been recorded, where the warmer colors indicate more activity. From Eyetracking heat map Wikipedia [Digital image], by Tschneider, 2017, Wikipedia (https://commons.wikimedia.org/wiki/File:Eyetracking_heat_map_Wikipedia.jpg). CC BY-SA 4.0

Figure 2
Example of Gaze plots



Note. A gaze plot will show the pattern in which the eye movements are displayed in order. An indication of how long the eye has lingered is presented with the size of the circles. There are three participants where green, blue, and red represent one each. From Gaze plot eye tracking on Wikipedia with 3 participants [Digital Image], by Tschneider, 2017, Wikipedia (https://commons.wikimedia.org/wiki/File:Gaze_plot_eye_tracking_on_Wikipedia_with_3_participants.png). CC BY 4.0

2.3 Previous Eye-tracking Studies

Throughout the years a large number of eye-tracking studies have been conducted. Carter & Luke (2020) wrote in their article “Best practices in eye tracking research” that between 1968 and 2018 over 1200 publications were found on the Web of Science using eye-tracking as the topic. The article also categorizes the studies into disciplines where 12.94% are under social sciences and education and 11.89% under engineering and technology, which would be the topics regarding the Maritime industry and for its use in education (Carter & Luke, 2020).

Maritime studies are mostly focusing on using the data for further education (Eklund et al., 2020) and more generally what the data can be used for (Hareide & Ostnes, 2017) rather than comparing novices and experts. Meanwhile, other industries have more “Novice vs. Expert” studies on eye-tracking. Some of these include aviation, medical, and construction industries where, just like in the maritime industry, lives could be lost if the work is not done properly.

Comparing novice and expert anesthesiologists, experts tended to focus on a specific location whereas the novices divided their attention between the target location and their tools. Experts “make more careful observations, have deeper cognitive processing and demonstrate less anticipation, together with more local processing and engagement with the task than novices.” (Capogna et al., 2020) Therefore, using gaze patterns of novices could be used as a warning system to aid in training and reduce errors (Capogna et al., 2020).

When comparing novice and expert airline pilots Xiong et al. (2016) showed that experts have shorter fixation times, a larger number of fixation points, greater scan frequency, and wider scan area compared to the novices. The study demonstrated a connection between eye movements and flight performance, where the better eye movements the pilot had, the better they performed (Xiong et al., 2016).

In the construction industry, Dzung et al. (2016) compared how novice and expert construction workers identified site hazards. The participants looked at several photos with various hazards and had to correctly identify them. The study claimed that identifying hazards is the most common method of reducing and preventing accidents, and adding more training may raise the safety and skills of the workers. The results of the study were that while the accuracy between the novices and the experts was similar, experts spent less time identifying the hazards, and the novices were less assured in their identification. (Dzung et al., 2016)

2.4 Maritime Eye-tracking Studies

The maritime industry has previously attempted to study how eye-tracking can be used for educational purposes (Atik & Arslan, 2019; Eklund et al., 2020; Hareide & Ostnes, 2017), as well as to see how it can be used to identify where the attention lies and if it needs to be corrected. Hareide & Ostnes (2017) found in their study “Maritime Usability Study by Analysing Eye Tracking Data” that the data can be used to optimize the layout of the bridge where the systems are set up, as some areas take up more attention than others (Hareide & Ostnes, 2017).

In a pre-study by Eklund et al. (2020), the authors describe how eye-tracking can be a way to transfer knowledge from pilots to cadets by both parties analyzing the eye-tracking recording to gain an understanding of their performance. They also mention that there are limitations to

using eye-tracking, as it can cause a mental load on the participant from knowing that they are being recorded and observed. Additionally, wearing glasses and lenses may interfere with the results as the glare from the lenses can cause the eye-tracking glasses to incorrectly read the eye movements (Eklund et al., 2020).

Another Novice vs Expert study by Atik & Arslan (2019) looking specifically at the ECDIS and radar, concluded that eye-tracking can be a useful means to gauge competence of the officers. Normal observation by the instructor is not always reliable to correctly judge how the student examines the situation. The study showed that novices spent more time looking at the ECDIS compared to experts, but the areas that were focused on the ECDIS were similar between the groups. On the radar, the duration and areas focused were more similar between the groups. Having more research and studies focusing on heat maps, gaze plots, stress/fatigue, and situational awareness would, according to the authors, prove useful. Also mentioning the cost of the equipment in the education as a hindrance, but one that should be worth the investment (Atik & Arslan, 2019).

3. METHODOLOGY

To answer the research questions in this study, a mixed method approach was chosen as both qualitative and quantitative data were deemed necessary to give a more complete picture of the results. Denscombe (2014) explains that “the use of more than one method can enhance the findings of research” (p. 207).

The second research question “Do participants' own perceptions of where they direct their attention the most match up with what they focus on during the simulation?” needed more insight and freedom in the form of qualitative data from the questionnaire, as closed questions would be too leading to yield any meaningful results. Furthermore, the qualitative data can show nuances to provide a discussion of why the groups answered the way they did even with a limited number of data points. The quantitative data was provided from the recordings and tracks, this is essential for answering if there are any differences in the executed approaches or key points of eye focus between the expert and novice groups.

3.1 Demographics

The sample groups participating in this study consist of one expert group and one novice group. The experts were Swedish maritime pilots, and the novices were 4th-year Master Mariner students at Chalmers University. The participants in both sample groups were chosen based on their educational background (see chapter 2.1), and availability regarding the scheduling at Chalmers. The novice group was made up of 10 participants, ranging in age from 22 to 28, with an equal number of men and women (5 each). The expert group, on the other hand, consisted of 6 participants with ages ranging from 47 to 58 and had a gender split of 4 men and 2 women.

3.2 Ethics

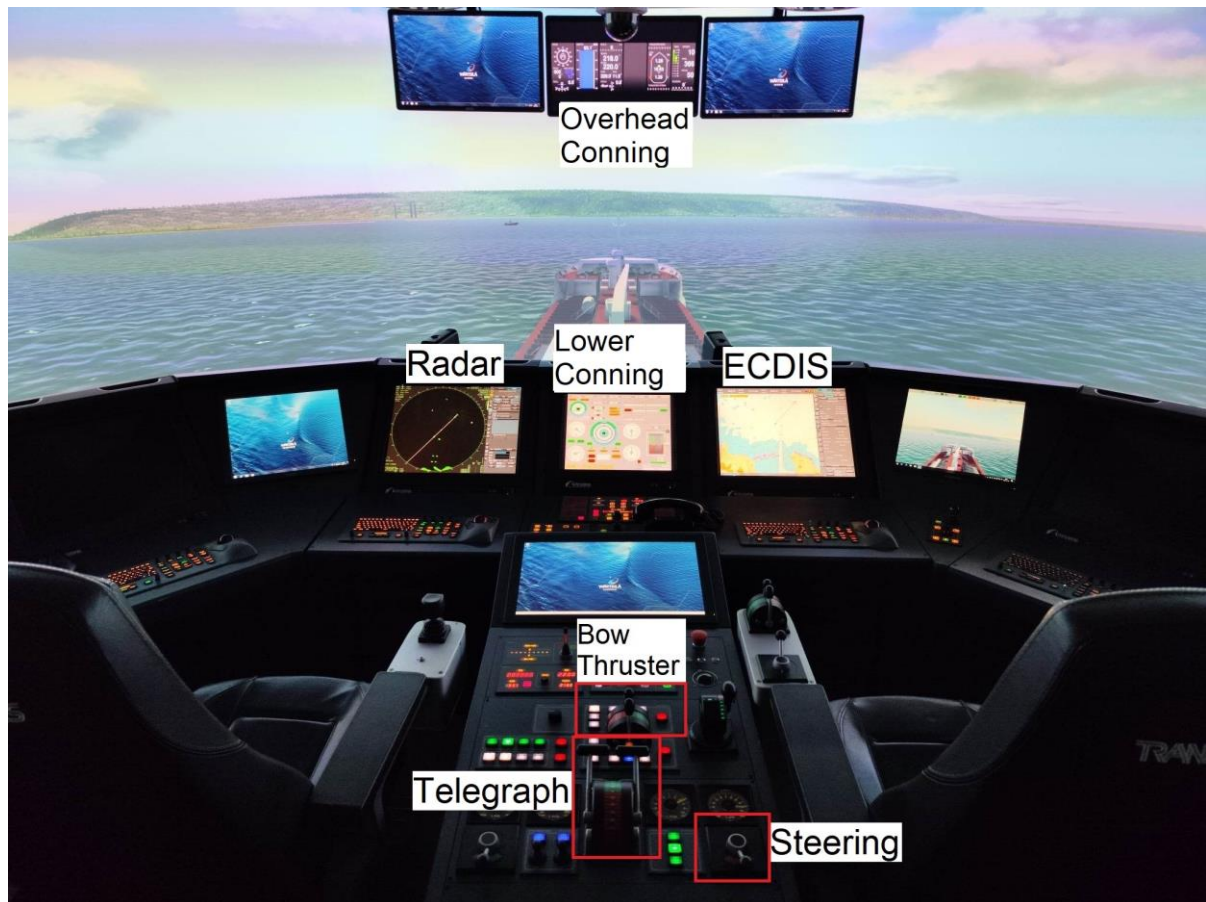
Before collecting data, the study required both experts and novices to fill out a consent form for ethical reasons, ensuring compliance with the use of recordings. The participants were informed about what the study entails and how the data will be used. To protect the confidentiality of the participants they were each given an identification number during the recordings and no names were used. The study follows the requirements of Article 28 of the EU General Data Protection Regulation (2016/679) when it comes to the processing of personal data.

3.3 Technical Setup

3.3.1 Bridge Setup

The Technical equipment used in this study was provided by Chalmers and the SMA. Chalmers has many different simulators on their campus at Lindholmen and the one used for this study is the Full Mission Bridge Simulator (FMBS) which has the software Wärtsilä's NTPro 5000 5.40 installed (<https://www.wartsila.com/voyage/simulation-and-training/ntpro-5000-simulator>). The FMBS is the best suited simulator for this study since it is more realistic than the alternatives found at Chalmers and has all the functions of a real bridge in a similar layout. The bridge used has a visual display of about 200°, radar, ECDIS, conning, steering, and propulsion instruments (Figure 3).

Figure 3
Bridge Setup



Note. Bridge equipment and screens visible in the heat maps.

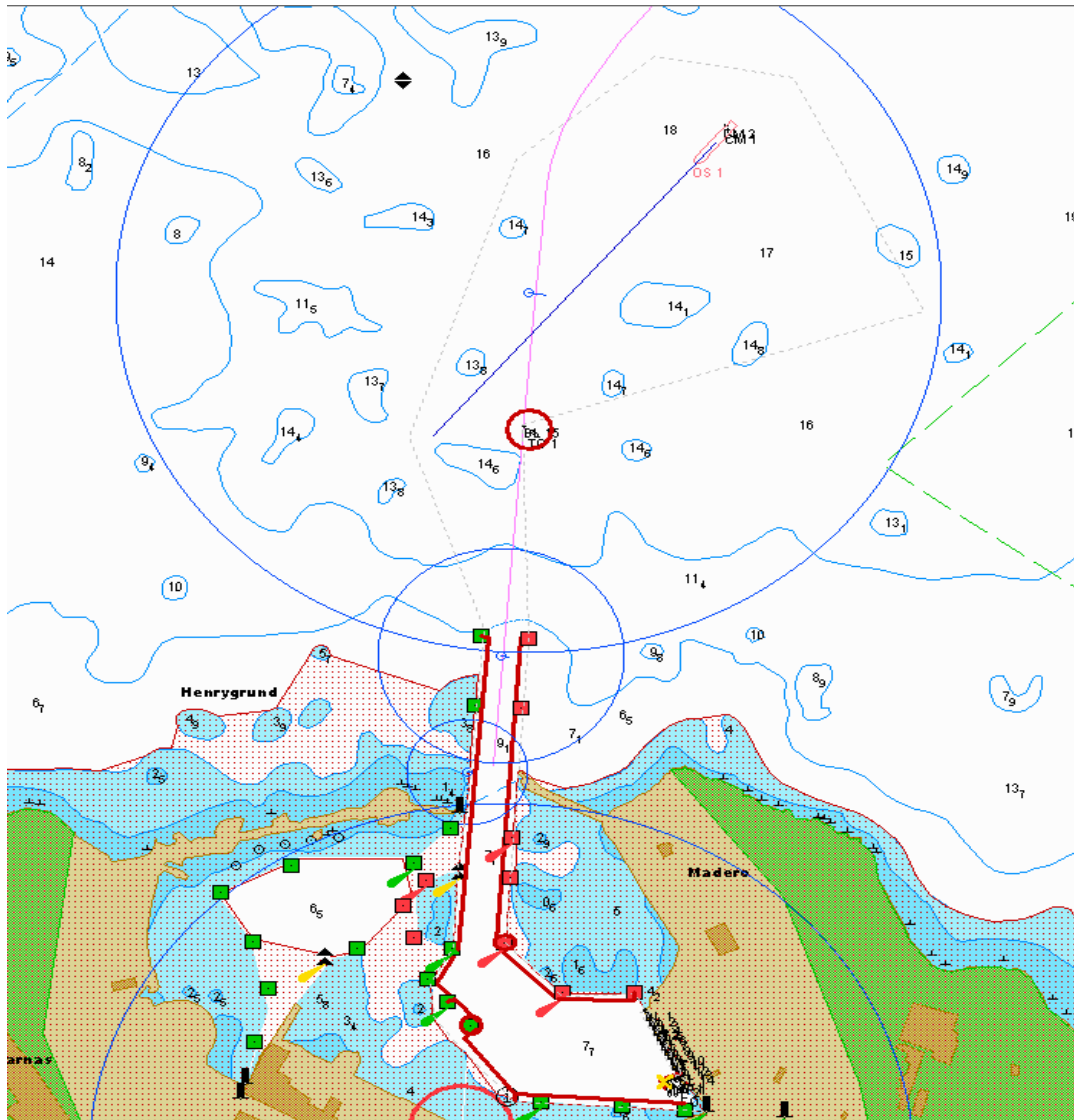
3.3.2 Tobii Glasses

Participants used Tobii Pro Glasses 3, which is a new model of wearable eye-tracking glasses that record video and audio (www.tobii.com). Using these glasses in the ship simulator to record allowed the development of heat maps to identify the gaze activity of the participants.

3.3.3 Scenario

The scenario was to hand-steer a product tanker (Table 1) to a harbor basin. Westerly wind, easterly current, a fishing vessel at the fairway approach, and a narrow fairway contributed to the challenges which needed to be overcome to successfully execute the approach (Figure 4).

Figure 4
Scenario Overview



- *Note.* Figure 3 shows an overview of the scenario. Blue rings are areas affected by current and wind. The small red circle in the middle is a fishing vessel at anchor acting as an obstacle.

3.3.4 Ship Model Used

A table of the most important ship data was produced to give an idea of what participants were using in the FMBS (Table 1).

Table 1
Ship data

Ship-model	Length	Breadth	Draught	Rudder	Propulsion	Bow Thrusters
Coastal Tanker 1	144m	21.8m	7m	Fishtail rudder, max 35°	CPP, left rotation	Yes, 850kW

3.4 Experimental Setup

3.4.1 Trial Runs

Before allowing the participants to take part in the study, a few trial runs of the scenario were conducted to make sure it was doable for 4th-year students and to see how much time would be needed. During these trial runs, it took approximately four minutes to set up the bridge and then between eight to ten minutes for the completion of the scenario.

3.4.2 Briefing

Before the simulations, a briefing with each participant was held where an overview of the scenario was presented (Figure 3), during which the parameters of the wind and sea were discussed, and the ship data was presented (Table 1). It was discussed that this was a scenario where participants will navigate to the harbor basin and approach as if they would go to berth with the starboard side. However, the berthing was not included. This meant they should not enter the harbor basin at full speed as this would not be a very realistic situation.

3.4.3 Participants' Setup of the Bridge

The only technical limitation participants had to abide by was hand-steering. All other instruments could be set up the way participants wanted, and the choice of approach was entirely up to them. Most participants chose to have north up on the radar/ECDIS, some chose to have relative motion and others chose true motion.

3.4.4 Simulation

Novices ran the scenario three times to provide more data, but also to make sure all of them finished successfully at least once. Experts ran the scenario twice because their proficiency in ship handling is much greater and a third run was deemed unnecessary after the first two runs, since the eye movements and approaches to the scenario were very consistent.

3.5 Data Collection

A protocol for the entire process of data collection was made in the way of a checklist to ensure no mistakes occur at any vital steps and to keep the process identical throughout the study to produce reliable data (see Appendix).

3.5.1 Questionnaire

After the scenario each participant filled out a brief questionnaire to extract some demographic data and some additional information.

The questions of the questionnaire were as follows:

1. How old are you?

2. What is your Gender?
3. How difficult did you find the scenario? On a scale of 1-5 where 1 is very easy and 5 is extremely difficult.
4. What is your position/professional title? (Expert group only)
5. Where do you perceive you were looking/focusing the most during the simulation? Name at least three.

Each question was designed to provide demographic data but also to provide some nuanced information. Age and gender are two key factors in a lot of experiments and that is why these metrics are included. As well as to show that the demographics are not being skewed for this study. The third question was included to possibly provide more information for further studies and less important for the results. Although this scenario during trial runs was perceived to be very difficult for novices, it was decided not to make any changes. A meeting with supervisors concluded that the scenario should be difficult so that participants must continuously stay focused during the simulation. It was implied that having a difficult scenario would make it easier to find distinguishing results between experts and novices. The last question on the questionnaire was to gather data regarding what participants perceived their focus lay. To find out if most participants have a good or bad understanding of where they direct gaze activity, which in turn may provide a better perception of where they use their resources.

3.5.2 Eye-tracking Recordings

Recordings from the Tobii glasses were saved on an SD card which were later transferred to a computer with the analysis software installed on it (www.tobii.com).

3.5.3 Simulator Tracks

After each simulator run in the FMBS, a log file is automatically generated by Wärsilä's NTPro software. Data included in the log files are among others speed, course, and position from the simulator runs.

3.6 Data Analysis

This thesis is based on quantitative and qualitative data, using a mixed methods approach including a questionnaire, observations of simulations, log files of FMBS tracks, and mapping of eye-tracking recordings from the simulations. Usually, questionnaires are used for quantitative data collection, however the questionnaire used for this study had an open-ended question that provided more qualitative data (Denscombe, 2014). The study is based on an activity distinguishable between the expert and novice groups created from quantitative data mapped out on images in the form of heat maps. The study consisted of Systematic Observations to reduce variations and produce more consistent data between observers (Denscombe, 2014). This was done by having all the participants perform the same scenario rather than comparing equivalent results from different scenarios. The study's observations were derived from simulation scenarios and were primarily gleaned from the analysis of recorded footage. The data provided from the recording analysis is quantitative as the mapping handles many data points.

3.6.1 Heat Map Analysis

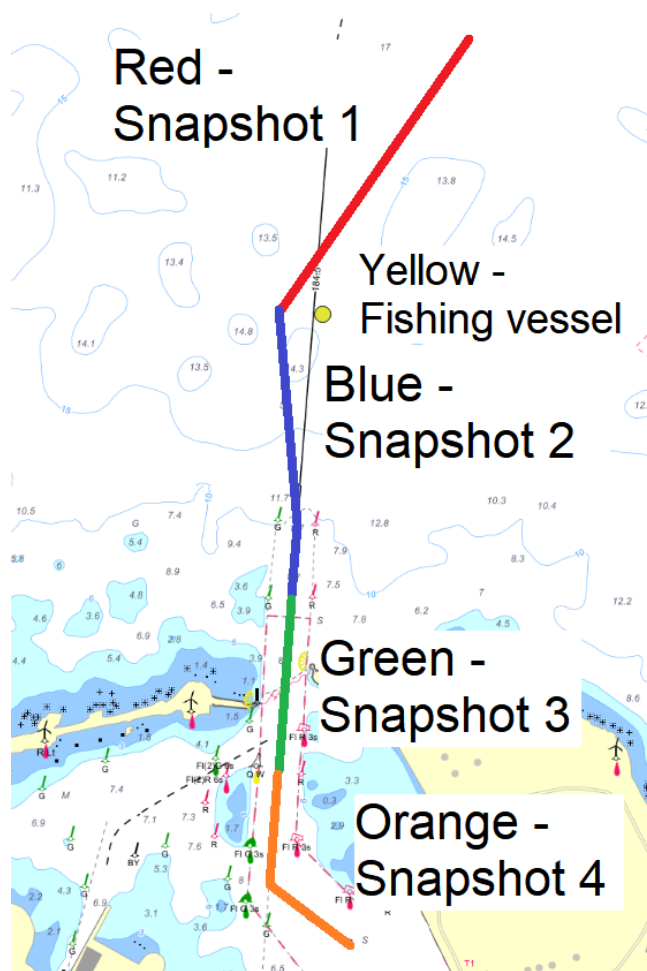
The snapshots are references for different time limits or sections of the scenario (Figure 5). When the software makes the heat maps it takes the averages of all instances of eye focus on specific points. Hundreds of instances make up colors on the snapshot. After the software had

mapped out the activity on the snapshots, comparing the results was much easier as it compiles a large set of data points in a single image. The software could compile multiple results or in other words, make new heat maps based on multiple other heat maps.

An example of how the snapshots work can best be explained by looking at snapshot 1 which covers the area from the start to the fishing vessel (Figure 5) because all gaze activity regarding the fishing vessel is caught in a single heat map.

A reoccurring theme in the heat maps was that a lot of gaze activity was directed right above the lower conning screen. Looking at these heat maps alone would suggest that the participants have been staring at the deck of the ship as mentioned in chapter 1.4. The probable cause is that the snapshot is taken at a higher elevation to include all the instruments in one picture and therefore the misalignment of the results from the recordings are due to the different angles.

Figure 5
Map of snapshot sections



Note. Figure 5 shows an overview of what each snapshot covers when mapping the heat maps from the recordings.

3.6.2 Heat Map Analysis of Participants

Analyzing the recordings was done using a software called Tobii Pro Lab (www.tobii.com), where the recordings are used in combination with four so-called snapshots which are reference

images. The software uses these images to compare what the glasses have picked up and map it out on the images to make a summary of the gaze activity in the form of heat maps.

The data used for this study are recordings from 16 participants. Ten students and six maritime pilots. As mentioned, the novice group participated in the scenario three times each, resulting in thirty recordings. The experts, on the other hand, provided twelve recordings. Due to unknown reasons in the analyzing software, only twenty-five of the novice recordings were able to be used, and eleven of the expert's recordings. All sixteen participants answered the questionnaire providing some additional information and nuances to the results. The recordings were split up into four different sections paired with the snapshots providing a more detailed picture of the gaze activity and more context to the results.

3.6.3 Questionnaire Analysis

Analysis of the questionnaire was done by content analysis (Denscombe, 2014), where the answers were put into smaller categories and divided between the expert and novice groups' answers. This was to easily differentiate the answers to get a better picture of the different mindsets of the groups. Following this the frequency was counted for each category to get a complete picture of what was relevant and reoccurring from the questionnaire. This was mostly done with the results of the last question as they were used to compare each group's open answers in relation to the heat maps to find out how the participants think and not just how they act and direct their attention. This took the form of a spreadsheet which was color coded by the groups and categories based on where the information was available for the participants and how similar the answer given was. For example, answers such as “course over ground”, “course” and “heading” were all put into the same category as they all cover the ship’s direction, representing a similar mindset between the participants.

3.6.4 Analysis of Tracks

Comparing how the different groups executed the port approach was done with the software QGIS 3.28.3 found on the QGIS website (www.qgis.org), which visualized tracks of the ship's positioning. This was done using the log files automatically generated by the FMBS software after each simulation run.

4. RESULTS

4.1 Passing the Fishing Vessel

The first snapshot is taken at the start of the scenario. This will encompass the fishing vessel, which participants will have to pass.

Figure 6

Heat maps Snapshot 1



Note. These are the heat maps compiled on snapshot 1. Experts (left) and novices (right).

Heat maps from snapshot 1 (Figure 6) reveal that the novice group directed most of their attention ahead of the ship. The green areas on the port side represent attention directed to the fishing vessel and some attention is directed to the various instruments such as radar, ECDIS, and conning screens [overhead and lower].

Experts' attention is focused on similar points such as the navigational equipment, ahead of the ship and the port side of the ship. The difference was that the expert group had more focus on steering and the engine telegraph. Another big difference between groups in snapshot 1 is the fact that the experts had a more concentrated focus on the sides of the ship.

4.2 Fairway Approach

The second snapshot encompasses data from after the participants passed the fishing vessel until the second pair of buoys in the fairway.

Figure 7

Heat maps Snapshot 2



Note. Heat maps showing what the experts (left) and novices (right) looked at during the second section of the scenario.

In Figure 7 the experts divided their attention mostly on the ECDIS and looking out, with a focus on the sides of the vessel. The secondary focus lay on the radar, the lower conning screen, and the engine telegraph. The novices, however, had their primary focus on the lower conning screen and looking out. Their secondary focus was on the overhead conning, the radar, and the ECDIS.

Comparing the two heat maps, it shows that the pilots have more focused points of observation. The points of focus are smaller, more intense and differences regarding what locations the experts and novices look at can be seen clearly.

4.3 Passing the Piers

The third snapshot has data from the second pair of buoys in the fairway to the cardinal mark in the basin.

Figure 8

Heat maps Snapshot 3



Note. These are the compiled heat maps from the experts (left) and novices (right) passing the piers in the fairway heading into the basin.

The third snapshot reveals that both groups are keeping their attention on mostly the same points. A similarity that can be seen compared to other segments in the scenario is that neither group uses the radar much. Experts pay more attention to the ECDIS, while the novices focus more on the conning screens. A reoccurring theme that is still pronounced in this snapshot, is the expert group's focus ahead of the ship which is split into a wider area that covers more of the sides of the ship compared to the novice group.

4.4 Harbor Basin

Figure 9
Heat maps Snapshot 4



Note. The final heat maps from snapshot 4 are taken right at the harbor basin where the berth comes into view on the port side and the current has shifted to wind.

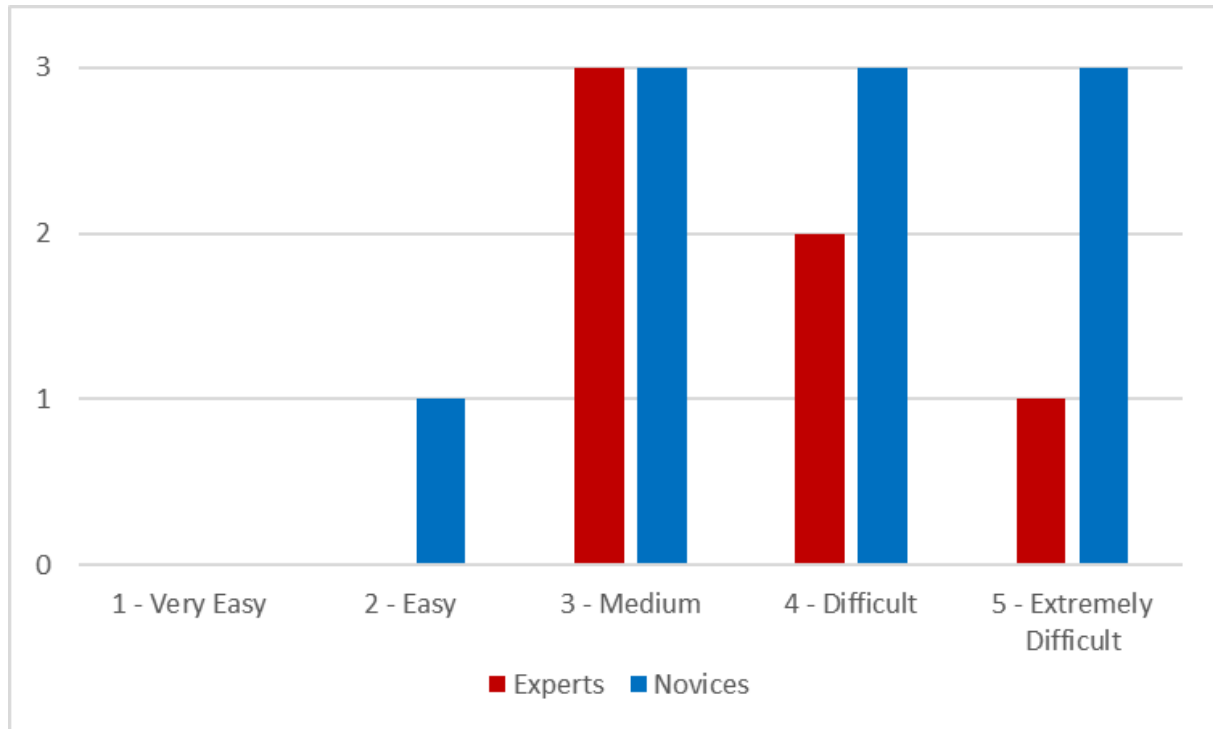
In the final section of the scenario, heat maps showed that novices direct a lot more attention to the conning and ECDIS screens. Attention ahead of the ship is also very concentrated to the front and not very divided to other parts such as the basin area and berth. Experts focused more on the engine telegraph, bow thruster and steering instruments. As well as the surrounding area and less on the navigational equipment.

4.5 Questionnaire Results

When asked how difficult the participants found the scenario on a scale of 1-5 where 1 was very easy and 5 extremely difficult (Figure 10). The novices were split, three answered extremely difficult, three answered difficult, three answered medium and one participant answered easy. Giving the scenario an average rating of 3.8/5. According to the pilots, three of them answered with medium difficulty, two answered difficult, and one answered extremely difficult, with an average rating of 3.66/5. This result was very consistent between both groups where the average rating of the scenario would be difficult when applied in the questionnaire's format.

Figure 10

How difficult did the participants find the scenario?

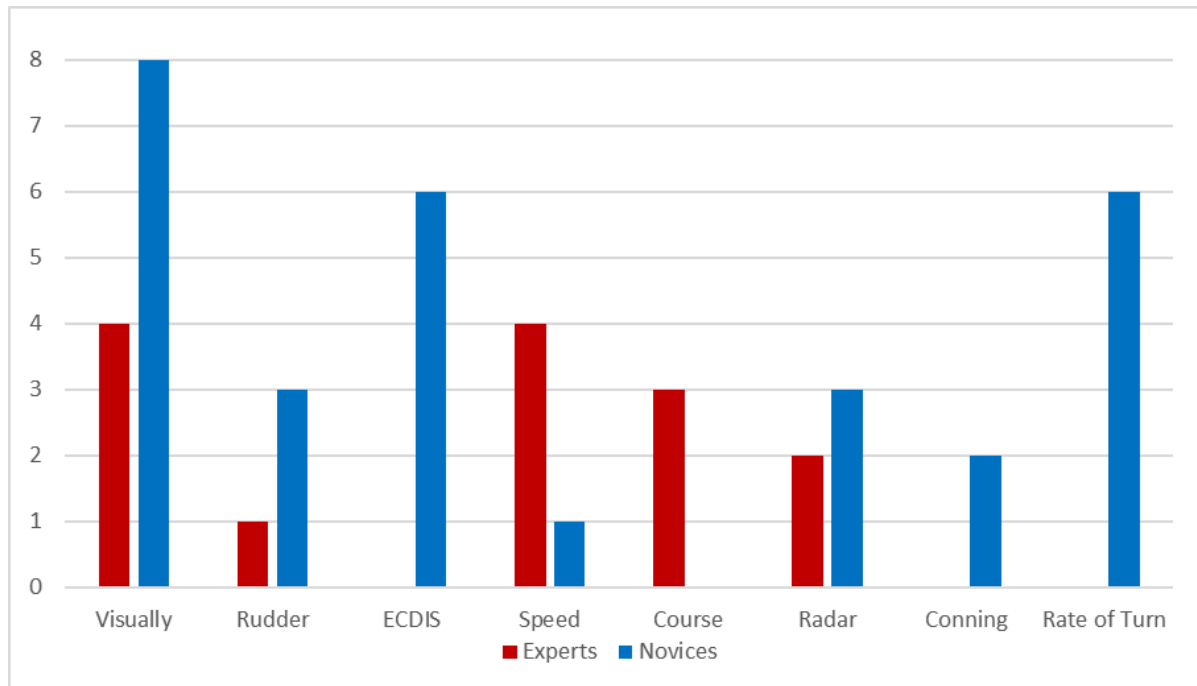


Note. Diagram of answers regarding how difficult the participants found the scenario.

The question about where the participants perceived they looked, was an open question giving different answers. To give a comparative result, answers meaning the same were compiled into the same category. For example, all answers regarding looking outside such as *the mast*, *the buoys*, or *out* were all placed in the category “Visually”. Likewise, answers that could be applied to multiple screens, such as course and speed were categorized on their own. Since it does not specify if they got the information from the conning, the ECDIS, or the radar. The rate of turn (ROT) and rudder were categorized outside of conning as it is a specified answer giving more context to the heat maps (Figure 11).

Figure 11

Where did the participants perceive they were looking/focusing the most during the simulation?

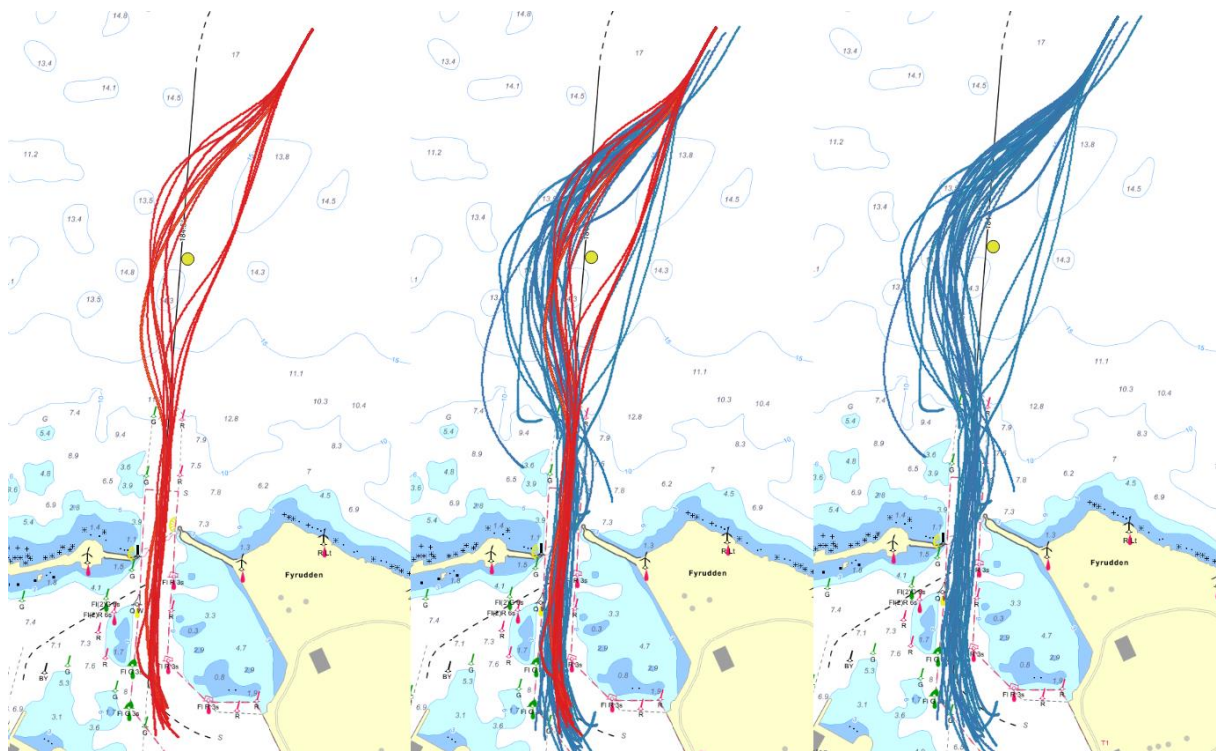


Note. Diagram of the answers given where the participants perceived were looking during the scenarios.

4.6 Tracks

The tracks from the simulations show the differences between the experts and the novices (Figure 10).

Figure 12
Tracks of the scenario runs



Note. Tracks of the experts (red) and the novices (blue), along with the fishing vessel presented (yellow dot).

The experts had less variation between their runs, showing more consistency. Within the novice group, they had a much greater spread of the tracks. Experts chose to turn more towards the fishing vessel, keeping the distance low and recognizing the space needed for the approach of the fairway. Novices had more variety in their approaches and more often kept a bigger distance to the fishing vessel making their approach towards the fairway very steep and in a few cases resulting in grounding the vessel on either side of the fairway or more commonly hitting one or two buoys.

Since the planned execution of the approach was not discussed beforehand and was left to the participants judgement, some participants opted to pass south of the fishing vessel. Looking at the tracks, the general trend of experts staying closer to the fishing vessel remains unchanged. The number of tracks from the novices opting for the south side of the fishing vessel only numbered three, while the number from the expert group was five. This means that novices opted for the other side 10% of the time while experts did 42% of the time.

5. DISCUSSION

5.1 Method Discussion

5.1.1 Mixed Methods Discussion

The mixed method used in this thesis was an appropriate choice reflecting at how and what kind of data was brought forth. Considering the research questions, it was decided that both qualitative and quantitative data would be needed to answer them with the most accuracy. Arguments can be made that the qualitative data received from the questionnaire could have been extracted from interviews which is correct. Interviews, however, would have required more work and thus time. Time was the most limiting factor during the study by far.

5.1.2 Demographics Discussion

Demographics used for this study were chosen as explained in chapter 3.1, this method of choosing was also a product of the lack of time and the same reason for not including more participants. Thoughts of including students from lower years were considered at first, but quickly disregarded as matching up schedules and available simulator times was difficult enough. The gender demographic for the study was almost 50/50 male and female.

5.1.3 Experimental Setup Discussion

Choosing a scenario was also a decision based on time limitations as explained in chapter 1.4. Discussions regarding the scenario have sprung up during the ongoing data collection. Berthing was always an interesting avenue to take with an eye-tracking study as there would potentially be many differences between the novice and expert groups. However, when contemplating this it was considered that there are probably very few expectations of a fresh 2nd officer or senior student, to be able to perform a perfect berthing by themselves as they start working on ships. Generally, berthing is performed by the captain, pilot and in some cases the Chief Officer with the master's guidance. This makes berthing appear less relevant than maneuvering as it is a task that will generally be practiced much later in the career of a maritime officer. As mentioned in chapter 3.5.1 regarding the difficulty of the scenario, having a more difficult scenario could potentially increase different outcomes. If a novice's mental resources are overloaded during a difficult scenario, it could provide interesting results. However, having too difficult of a scenario could affect the results by providing fewer successfully completed runs.

5.1.4 Technical Setup Discussion

The equipment used for this study is the Tobii Pro Glasses 3. Overall, both the eye-tracking equipment and the accompanying software were easy to use. The most limiting factor about the eye-tracking equipment was that prescription glasses did not work in combination with the equipment. The limitations of the glasses could have affected the results of the gaze activity, where one participant of the expert group mentioned he had a hard time seeing the values on some of the screens, therefore, disregarding them. It is not farfetched to assume that some of the other participants that required glasses could have more activity on some of the instruments if they could see properly.

FMBS is the most realistic simulator available at Chalmers and was the best choice for running this scenario where getting a realistic environment is very important. The more realistic the simulator environment the more reliable and applicable the results are deemed to be.

5.1.5 Analysis Discussion

Tobii Pro Lab was an analyzing software paired with the glasses, that could show the recordings and the eye movements while the mapping was working in the background. However, the mapping process took a considerable amount of time and some of the recordings, entirely or in

parts, were unable to be mapped even when there was nothing seemingly wrong with the recordings. The mapping process would stop at 100% and would not finalize, leading to a lot of time being spent and some data being lost. Losing time and data was a crucial detriment when both were scarce resources for this study. Although this was an unfortunate outcome this technical issue will most likely be fixed by Tobii in the future. Pro Lab is a software with capabilities to present data in more ways than what is exhibited in the study such as gaze plots. This was originally the plan, but as time was limited that decision was changed to only include heat maps.

Producing the heat maps from the recordings included the selection of snapshots. Consideration regarding this was made since the more snapshots used the more accurate heat maps will be produced. Four snapshots were decided on (Figures 6,7,8 and 9) as more snapshots used would entail more time spent on mapping and presenting the heat maps. These four snapshots were chosen based on what can be seen in those sections of the scenario but also in consideration of what the participants could be focusing on (Figure 5). This meant the snapshots should not cover too large an area, where some gaze activity might change and would then be less accurately presented as it gets summarized with other parts.

The first snapshot covers the entire section where the fishing vessel could be seen as it was an obstacle that participants would have to pay attention to. The second snapshot would cover the section between the fishing vessel and the start of the fairway as the approach was important and navigational equipment was more in focus up until the narrower areas. The third snapshot was captured in the fairway with a clear view of the piers as these are landmarks that could draw some attention from the participants and would be clearly displayed on the heat maps. In the more narrow fairway, a shift of gaze activity on the instruments was also considered. The last snapshot was covering the harbor basin where another shift in focus to propulsion instruments would happen and the attention to the berth would also be covered by the snapshot.

Looking back at the questionnaire and the second research question, regarding where participants perceive to have focused could be more specific. That could have yielded even better answers and provided more insight as to where and how participants think they use their instruments compared to what they actually do.

Analysis of the tracks was done using QGIS for the ability to present the tracks in a very good and customizable way. A good presentation of the tracks visually makes comparisons and finding differences much easier.

5.2 Heat Map Differences Between Experts and Novices

The first research question of this study was to observe if there were any differences between the heat maps generated from the expert and novice groups. The reason for asking this question is well stated in chapter 2.4 “In a pre-study by Eklund et al. (2020) the authors talk about how it can be a way to transfer knowledge from pilots to cadets by both parties analyzing the recording to gain an understanding of the performance”. Before using eye-tracking as a tool for education, a difference must be found to justify the need for new technology. If no differences are found there would be no point in implementing new technology to help develop new skills or transfer knowledge that is already present.

5.2.1. Passing the Fishing Vessel

Comparing the passing of the fishing vessel in the scenario (Figure 6), the expert group kept a greater focus on instruments than the novices. The propulsion instruments pose the greatest difference among them. Experts also had a greater focus on the fishing vessel and comparing the tracks the expert group generally had a closer approach to the fishing vessel (Figure 12). As mentioned in chapter 4.6, experts also chose more frequently to pass south of the fishing vessel (32% more often than the novice group). This is reflected in the heat maps as a lot of activity can be seen on the starboard side of the ship.

Novices are focusing mostly on the conning screens [overhead and lower] and straight ahead of the vessel. A potential reason could be that the novice group had very little experience with steering a large ship in such strong currents. This caused them to focus a lot more on the rudder order, ROT, and looking at the bow of the ship to better understand how the ship would behave. Both rudder order and ROT can be found on both the lower and overhead conning screens. Another reason for the lesser focus on the fishing vessel could be attributed to the approach of the novice group. As they generally kept more distance from the fishing vessel (Figure 12), perhaps the decision to direct attention elsewhere was made either consciously or subconsciously. Experts were using the radar more and overall divided their attention between the different instruments more evenly. This may also be attributed to the fact that experts are more comfortable using hand steering and have more experience with similar situations. Therefore, using less concentration or mental resources for the same tasks, allowing for example the use of radar more as a navigational aid to verify the information. Comparing this to the study by Capogna et al. (2020), where experts focused less on their tools than their novice counterparts, this provides an interesting contrast as it would imply the opposite for the maritime experts. In a study by Kasarskis et al. (2001), experts were shown to have shorter dwell times, in other words, focused on different points for shorter periods. This can be confirmed just by comparing heat maps from the different groups and verifying that the experts pick up the necessary information quicker and move on to the next step.

5.2.2 Fairway Approach

Comparing the fairway approach (Figure 7), there is still a difference between the experts and novices although not as pronounced as in the first section. The biggest difference depicted in the heat maps is the use of the conning screens. Novices use both conning screens quite a lot compared to experts as is the case in the first section as well, only not as obvious. As previously mentioned, this may be related to the first speculation about the novice group being unfamiliar with the strong current and therefore needing to pay more attention to the ROT on the conning screens. During the first and second sections, the current is the strongest and therefore one could possibly argue that the first half of the scenario is the most difficult. Experts used the engine telegraph more during this section as well and observations of the recordings confirm that the expert group was adjusting their speed more frequently. Another common factor that the second section had was the spread of the visual gaze activity. Experts again have split their focus a bit more on the surrounding area ahead of the ship and not just straight ahead. Constantly taking in new information and acting on it with a refined routine.

5.2.3 Passing the Piers

The third section's (Figure 8) heat maps were very similar to the second section. Both sections handle many of the same challenges, therefore getting very similar results can be expected. A variable that makes the results regarding the overhead conning screen interesting, is that the eye-tracking equipment did not allow for the use of prescription glasses as mentioned in chapter 3.5. The overhead conning screen is positioned a bit further away, making it harder to read the values without the help of corrective lenses. Most likely, this had a greater effect on the expert

groups' results, as four out of six experts needed corrective lenses and therefore chose to mostly ignore the overhead conning screen.

5.2.4 Harbor Basin

The harbor basin section of the scenario (Figure 9) has some similar differences found in earlier sections such as gaze activity on both the conning screens and activity surrounding the area ahead of the ship. A major difference compared to earlier sections of the scenario is the focus on the ECDIS between the groups. This section is the first where the novice group had more activity on the ECDIS than the expert group. Other trends are generally the same as other sections, the engine telegraph attention is still greater among the expert group, however, engine telegraph activity is greater in the novice group compared to the previous sections. From observations made during recording, the novice group would generally keep the same engine telegraph setting throughout most of the run and started adjusting the speed around the time they pass the piers.

5.3 Participants' Perception Compared to Heat Maps

For the second research question a comparison of questionnaire results and heat maps is made to find out how well the participants' own perception of what they are focusing their attention on. Looking at Figure 11, there were eight different answers included in the results, as explained in chapter 4.5 these answers intend to give context to the results.

A noteworthy observation is that none of the experts answered that their focus lay on the ECDIS, while the heat maps showed that they spent a lot of focus on it. However, that can be explained by the ECDIS also displaying speed and course which experts state as being some of their most focused points. The speed and course were two areas that the experts did focus on (as depicted in the heat maps), particularly adjusting the speed, which corresponds to the questionnaire answers. The majority of novices answered that they were focusing on the ECDIS, and this is something clearly displayed on the heat maps.

Both the expert and novice groups answered that they had their focus outside the vessel, which does correspond with the heat maps. About a third of each group mentioned radar and comparing it with the heat maps, it clearly shows that this was a focus point for the first half of the scenario, although not one of the main points of focus when looking at the entire scenario. An interesting discovery when looking at questionnaire results was the wording of the answers, and it becomes apparent that the groups think about the points of focus differently.

Generally, participants seemed to have a good perception of where they were directing their attention when comparing heat maps, recordings, and questionnaire answers. Although the limited data gathered was pointing toward participants having a good self-perception where they direct their attention, there is not enough to draw any general conclusions about mariners.

5.4 Comparing the Tracks Between Experts and Novices

The tracks in Figure 12 show that there is a variance between the experts and novices. When looking at the entire runs, the experts show better ship handling, as none of them ran aground and they all entered the fairway without issues. They also had consistent tracks among the group, showing that there was less swaying of the course and that they had better control. Looking at the novices, their rate of success was lower, with tracks showing attempts that had run aground. Entering the fairway was also shown to be more difficult, as entries after the first pair of buoys were made. All this correlates with the fact that having a good approach increases

the chances of successfully completing the scenario. Entering and having a good line through the fairway was largely attributed to the approach and the experts had a better idea of this beforehand and had better ways of making sure that the approach and execution were handled as smoothly as possible. Novices having a wide spread of tracks in the fairway and approach around the fishing vessel, showed that they had a harder time getting a good approach that would lead to an easier fairway execution.

As discussed earlier, a potential reason why it differs is that the novice group does not have a lot of experience navigating with a strong current and they were not prepared for how strong it would be. Even though this was mentioned in the briefing, having a lack of experience with these types of variables can still be very challenging. While the experts are maritime pilots whose profession is to navigate ships through difficult waters, giving them an edge with decades of experience at sea.

6. CONCLUSION

This study highlights a significant difference between the expert group and the novice group, which is evident across all areas analyzed. All the questions presented were answered.

The experts exhibited a more concentrated gaze on multiple different areas during the scenario. Comparing Figures 6, 7, 8, and 9 it can be observed on the heat maps that experts generally were directing more of their attention to the instruments, looking more at different points in the surrounding area and not just straight ahead of the ship. Novices paid more attention to both conning screens during the whole scenario and most gaze activity was focused straight ahead of the vessel. There are minor differences that are brought to light in chapter 5.2, but the ones mentioned previously are the most significant ones.

The expert and novice groups did have a good grasp of where their focus was when looking at the answers they gave and comparing them to the heat maps and recordings. The only difference among the groups was the fact that some answers in the expert group were a bit more specific in the wording of what they paid attention to such as course and speed.

Comparing the tracks, it is very evident that the experience that maritime pilots have made a big difference when it comes to the approach of a maneuvering scenario and when gathering and using information. The tracks show that the experts have much more consistent approaches that come up a lot closer to the fishing vessel setting them up for a straighter line toward the fairway. Novices generally had a much more diverse approach where most of the participants kept a far distance from the fishing vessel leading to a more difficult approach and some failed runs.

6.1 Recommendations for Further Research

The “Expert versus Novice” format is a relatively unresearched area and there is a lot that can be researched. Using the eye-tracking results for an educational purpose to teach students was considered, but due to the scope, it was left out. This would potentially require an expert to give a “correct” way to look as an answer sheet/recording. Gaze plots and the pattern of how the pilots and students look is other avenues that can be explored. A more mathematical study measuring the results and presenting values could be valuable.

The difficulty of the scenario had an average rating of around 4/5 according to the answers from the questionnaire. This was the level of difficulty that was aimed to provide a difficult challenge for the novice group to find differences between the groups that could have gone unnoticed in an easier setting. For future endeavors with similar studies, a scenario with strong currents could provide a significant challenge and can be explored further.

A study using COLREGS situations could be another avenue to take regarding eye-tracking, to see how behavior changes and what information is being focused on. Other situations focus more on the navigational aspects, or communication as the glasses has a microphone built in. Doing a study on specific instruments is also a possibility as the option of using snapshots of individual instruments and screens is easy to apply.

REFERENCES

- Atik, O., & Arslan, O. (2019). Use of Eye Tracking for Assessment of Electronic Navigation Competency in Maritime Training. *Journal of Eye Movement Research*, 12(3), 1–15. <https://doi.org/10.16910/jemr.12.3.2>
- Bell, C. (1823). *On the motions of the eye, in illustration of the uses of the muscles and nerves of the orbit*. <https://royalsocietypublishing.org/>
- Capogna, E., Salvi, F., Delvino, L., di Giacinto, A., & Velardo, M. (2020). Novice and expert anesthesiologists' eyetracking metrics during simulated epidural block: A preliminary, brief observational report. *Local and Regional Anesthesia*, 13, 105–109. <https://doi.org/10.2147/LRA.S267879>
- Carter, B. T., & Luke, S. G. (2020). Best practices in eye tracking research. *International Journal of Psychophysiology*, 155, 49–62. <https://doi.org/10.1016/j.ijpsycho.2020.05.010>
- Chalmers. (2023, February 8). *Sjökapten, sjökaptensexamen*. <https://www.chalmers.se/utbildning/hitta-program/sjokapten-sjokaptensexamen/>
- Delabarre, E. B. (1898). A Method of Recording Eye-Movements. *Source: The American Journal of Psychology*, 9(4), 572–574.
- Denscombe, M. (2014). *The Good Research Guide For small-scale social research projects* (Fifth edition). Maidenhead : Open University Press, 2014.
- Duchowski, A. T. (2017). *Eye tracking methodology: Theory and practice: Third edition*. In *Eye Tracking Methodology: Theory and Practice: Third Edition*. <https://doi.org/10.1007/978-3-319-57883-5>
- Dzeng, R. J., Lin, C. T., & Fang, Y. C. (2016). Using eye-tracker to compare search patterns between experienced and novice workers for site hazard identification. *Safety Science*, 82, 56–67. <https://doi.org/10.1016/J.SSCI.2015.08.008>
- Eklund, R., Sellberg, C., & Osvalder, A.-L. (2020). From tacit knowledge to visual expertise: Eye-tracking support in maritime education and training. In *Advances in Intelligent Systems and Computing: Vol. 1211 AISC*. https://doi.org/10.1007/978-3-030-50896-8_39
- Hareide, O. S., & Ostnes, R. (2017). Maritime Usability Study by Analysing Eye Tracking Data. *Journal of Navigation*, 70(5), 927–943. <https://doi.org/10.1017/S0373463317000182>
- Hetherington, C., Flin, R., & Mearns, K. (2006). Safety in shipping: The human element. *Journal of Safety Research*, 37(4), 401–411. <https://doi.org/10.1016/j.jsr.2006.04.007>
- International Maritime Pilots' Association. (n.d.). *Maritime Pilots*. Retrieved February 13, 2023, from <https://www.impahq.org/maritime-pilots>
- Kasarskis, P., Stehwen, J., Hickox, J., Aretz, A., & Wickens, C. (2001). Comparison of Expert and Novice Scan Behaviors During VFR Flight. *Proceedings of the 11th International Symposium on Aviation Psychology*.
- le Coze, J. C. (2022). The 'new view' of human error. Origins, ambiguities, successes and critiques. *Safety Science*, 154, 105853. <https://doi.org/10.1016/J.SSCI.2022.105853>
- Martinez-Marquez, D., Pingali, S., Panuwatwanich, K., Stewart, R. A., & Mohamed, S. (2021). Application of eye tracking technology in aviation, maritime, and construction industries: A systematic review. *Sensors*, 21(13). <https://doi.org/10.3390/s21134289>
- Sveriges Riksdag. (2008). *Förordning (1982:569) om lotsning m.m.* https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-1982569-om-lotsning-mm_sfs-1982-569
- Swedish Maritime Administration. (2022). *Några av våra yrkesroller*. <https://www.sjofartsverket.se/sv/om-oss/jobba-hos-oss/nagra-av-vara-yrkesroller/#lots>
- Xiong, W., Wang, Y., Zhou, Q., Liu, Z., & Zhang, X. (2016). The research of eye movement behavior of expert and novice in flight simulation of landing. *Lecture Notes in Computer*

Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 9736, 485–493. https://doi.org/10.1007/978-3-319-40030-3_47

Tschneider. (2017). Eyetracking heat map. [Digital Image]

Wikipedia. https://commons.wikimedia.org/wiki/File:Eyetracking_heat_map_Wikipedia.jpg

CC BY-SA 4.0

Tschneider. (2017). Gaze plot eye tracking on Wikipedia with 3 participants. [Digital Image].

Wikipedia.

https://commons.wikimedia.org/wiki/File:Gaze_plot_eye_tracking_on_Wikipedia_with_3_participants.png. CC BY 4.0

APPENDIX

Data Collection Protocol

Preparing Simulator:

First, we will prepare the scenario in the simulator and make sure everything is in working order before the participants arrive. Second, we prepare the glasses and computer to make sure all the data-collecting equipment is in working order. The time required for this will be longer in the beginning as we are still unused to how the simulator works and is set up, but the more we do it, the shorter it will take. At the start, we estimated it would take us a little less than an hour to prepare.

Consent and questions:

The participant arrives and we will fill in the consent form and answer any questions regarding the study and data collection. We are estimating this will take about 5 minutes depending on the number of questions.

Briefing:

We brief the participants about the scenario they will be doing, what weather and sea state they can expect, what the traffic is like, and what ship specifics they are working with. We will remind the participants that they will not complete berthing but are expected to treat the scenario and approach it as if they would be berthing at the starboard side. If there are not too many questions this step is expected to be around 5 minutes.

Bridge Setup:

The participant is given time to set up the bridge to their liking. No instruments will be excluded except for the autopilot, as this is a ship-handling scenario. We anticipate this will take around 5 minutes.

Scenario:

The Scenario performed will include a maneuver past a fishing boat and into a narrow fairway, and a turn in the basin of the port. There will be a strong current at the start of the scenario that will persist through most of the narrow fairway. In tests we did prior to participants, the scenario will take around 8 minutes to complete.

Questionnaire:

We will have some questions prepared on survey monkey after the scenario is done. These questions will consist of demographic data and how the experience was during the simulator scenario. The survey will take around 5 minutes to complete.

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2023
www.chalmers.se



CHALMERS