

Comparative study of the Skjold-class bridge- and simulator navigation training

Abstract

This paper presents a comparative analysis of the visual focus of the navigator during a passage in Norwegian littoral waters and in a maritime bridge simulator. The research project collects time distribution data of the navigator's visual focus on the primary components in the Integrated Navigation System (INS) and looking out the vessels windows. Data is collected by the use of Eye Tracking Glasses (ETG). The ETG registers the visual focus of the navigator, and this is used to generate statistics on which Area of Interest (AOI) the navigator is focusing on. Based on the ETG data AOI and Key Performance Indicators (KPI) are selected to further analyze the difference and similarities between navigation training on board and in a simulator. Findings indicate that use of a simulator is efficient when it comes to navigation training, and provides the same training outcome as on board navigation training. The results also indicates that a simulator passage is a more demanding cognitive process requiring a higher mental workload.

Key Words

1. Simulator 2. Military navigation 3. Eye Tracking 4. High Speed Craft

1. Introduction

Both ship owners and maritime education establishments are using simulators in greater extent to provide the navigator and navigation team with better preconditions in conduct of the on board job. Simulator training provide specialized navigation training and is used for efficiency reason compared with on board navigation training.

The maritime industry and users has been through a paradigm shift with the introduction of electronic navigation aids. Electronic Chart Display and Information System (ECDIS) has become mandatory on most ships to provide increased situational awareness for the officer of the watch (OOW).

This article provides a comparative field- and simulator study, to identify differences and similarities in visual attention, cognitive and mental workload of the navigator, based on the collected Eye Tracking data. Mental workload measurements, as part of team performance evaluations, has been found to correlate between simulator and field exercises (1). The hypothesis of the article is that field study data is similar to simulator study data, and thus simulator navigation training is efficient and should be further developed.

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2. Method

2.1 Skjold-class Corvette

The Royal Norwegian Navy (RNoN) launched the Skjold-class corvettes in 2010 (2). The vessels are built for rapid deployment along the Norwegian coastline and in Norwegian territorial waters, with speeds exceeding 60 knots.



Figure 1: Skjold-class Corvette in Norwegian Littoral Waters

The Norwegian coastline presents challenging waters for navigation, making the demand for navigation training high in the RNoN.

The Skjold Class navigation team consist of a navigator

(starboard seat) and an OOW (port seat). Three screens are placed in front of the OOW and the navigator, set up shown in figure 2. The navigator plans and conducts the passage while the OOW monitors and controls the passage.

Becoming an OOW involves passing several navigation test, several of which are performed in a simulator. A Skjold-class navigator receives approximately 80% onboard training during operation and 20% specialized simulator navigation training (estimates from Norwegian Corvette Service).

2.2 Simulator

In 2008 the Royal Norwegian Naval Academy (RNoNA) inaugurated a full scale Skjold-class bridge simulator with the same software and hardware as on board (1:1), with the purpose to gain effective navigation training for Skjold-class navigation crew. The visual scene provides a 210-degree image for the navigation team, all in 1280x1024 resolution. The visual database covers the majority of the Norwegian coastline. The topography and man-made objects are similar to reality, but there is less level of detail when it comes to buildings and non-navigation related objects.

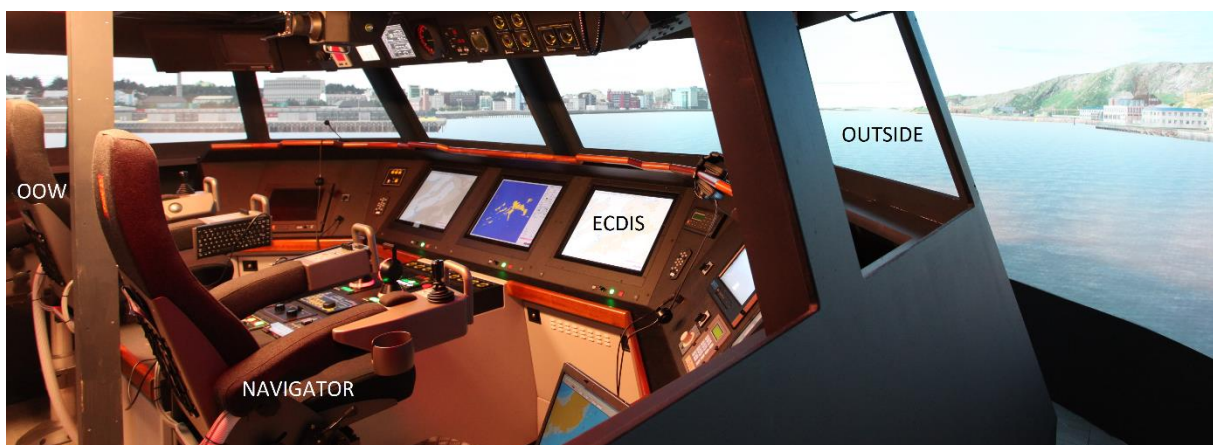


Figure 2. Skjold-class simulator at RNoNA. Navigator is places in the right seat, OOW in the left seat.

2.3 Eye Tracking

The data set is collected by second-generation ETG from SensoMotoric Instruments (SMI ETG 2w©). Calibration and recordings were conducted in accordance with operation procedures, and is processed utilising the BeGaze software (3).

A challenge was identified using the ETG during twilight and in use together with binoculars. The ETG limits the normal use of binoculars, and the glare in the glasses prevented optimal detection of small objects in twilight.

Eye Tracking equipment has been used to evaluate and improve the training process on ships` navigational bridge simulator (4), and also for stress classification (5). Furthermore ETG has been used by Forsman et.al (6) to evaluate the conduct of a passage with regards to experience of the navigator. It has also been used for validation of simulator for assessing difference in information interfaces (7).

2.4 Participants

The experience of the participant was between 2 and 6 years of active service as a navigator on board a Skjold-class corvette. The participants have conducted the four-year Naval Academy navigation and officer training. All participants were accustomed with the use of the Skjold-class bridge simulator.

2.5 Design

The field study and the simulator study were conducted in two different parts of Norway, due to vessel program limitation. The area where the field study and the comparative simulator study was conducted is similar concerning topography, but not identical.

The field study data collection was conducted in late November 2015, and the area of operation stretched from Sandnessjoen in north to Bergen in south. The weather was challenging, with rapid shifts of visibility from more than 5 nautical mile (NM) to 0,5 NM in seconds. The field study involved three navigators. Eight recordings were conducted, each with approximately 9 minutes recording time.

The area specific of the data collection in the simulator consisted of the littoral waters on the west coast of Norway between Maaloey and Sognefjorden, which is an area where the simulator database has a high resemblance to the real environment. The simulator study involved three navigators, seven recordings were conducted, each with approximately 10 minutes recording time.

It was a challenge to replicate the exact weather conditions in the simulator. Weather conditions were fixed at; wind 5 m/s from northwest, 0-0,5 metre wave height, good visibility with lights visible (20% darkness in simulator). Traffic density was set to normal in accordance with the area the ship operated.

Some of the navigators participated in both the field study and the simulator study. The navigational experience of the personnel participating in the comparative studies is similar. Table one outlines the differences between the variables experience, area, visibility, traffic density and period for each trial.

Table 1: Outline of the eight trials conducted.

Trial	Participant number	Experience	Area comparison	Visibility field study	Traffic density	Period
#1	1	2 years	Similar	>5NM	High traffic areas	F: 9min S: 10min
#2	F: 2 S: 3	F: 3 years S: 3 years	Start of field study more challenging	Varying	F: Demanding situation S: 2 vessels	F: 9min S: 11min
#3	4	7 years	Similar	>5NM	Normal	F: 11min S: 10min
#4	1	2 years	Similar (1)	0,5 - 5NM	Low	F: 11min S: 10min
#5	1	2 years	Similar (1)	>5NM	Low	F:10min S: 10min
#6	1	2 years	Similar (1)	>5NM	F:5 vessels S: 2 vessels	F:11min S: 10min
#7	F: 2 S: 4	F: 3 years S: 7 years	Similar	>5NM	F: None S: 2 vessels	F: 3 min ³ S: 11 min
#8	F: 2 S: 3	F: 3 years S: 3 years	Similar	>5NM	F: High S: 3 vessels	F: 7min S: 10min

F= Field study, S=Simulator, 1= Field study unfamiliar open area. Simulator familiar confined waters.

AOI was defined through a pre-study in the simulator, where eye movement data was analysed to identify which areas on the bridge took the navigators attention. For the comparative study of the Skjold-class bridge navigation and simulator training, AOIs *Outside* (AOI_o) and AOI *ECDIS* (AOI_E) has been identified as the two primary areas, illustrated in figure 2. This is because the main difference of navigation training in the field and in the simulator are the projected reality on screens in the simulator, and the working environment concerning noise and movement.

3. Result analysis

15 datasets were collected among the participants with a total duration of 2 hours and 25 minutes. KPIs in the AOIs, scanpaths, sequence charts was generated, in addition to statistics in Excel for eye movement data (3). An example of a scanpath is shown in figure 3, identifying fixations and saccades. Fixation is defined as the state when the eye remains still over a period of time (>80 ms), and saccade is defined as the rapid motion from one fixation to another (8). In figure 3, fixation time is given by the size of the circles and saccades is illustrated by the lines between the circles.

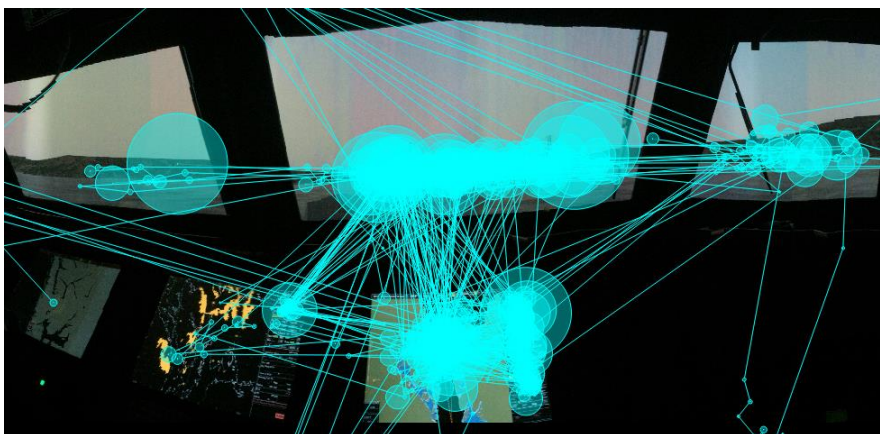


Figure 3: Scanpath of participant 4

³ Aborted due to disconnection of ETG

Based on the hypothesis, three out of nine KPI were identified for use in the further analysis with comparison of the field study data and simulator study data. Dwell time could reflect the importance of an AOI (9). Average fixation time is used as an indicator of cognitive and mental workload for the navigator in the AOI and fixation rate is an indicator of task difficulty (8).

The statistical model consisted of a normality test, an F-test and a t-test to control if the values disprove the hypothesis that field study data and simulator data is similar within a significance level of 5%. The F-test is conducted to control the p-value for validation of similarity of the data set. The t-test is conducted to control if the expectations values in the data set are valid.

KPI → AOI ↓	Trial	Dwell time	P-value	Average Fixation	P-value	Fixation Rate	P-value
Outside	Field study	59,7%	0,69	432 ms	0,96	71,4	0,98
	Simulator study	56,4%		517 ms		61,9	
ECDIS	Field study	22,4%	0,09/0,62 ⁴	293 ms	0,26	40,7	0,08/0,19 ⁵
	Simulator study	22,1%		312 ms		35,3	

Table 2: KPI variables for AOI with p-values.

All values are above the significance level of 5% and the statistical test does not disprove the hypothesis that field study data is similar to simulator data.

3.1 Dwell time

In AOI_o there is a difference of 3,3% between the field study and the simulator study. A reason for this difference could be that the real world has more details than the simulator, leading to a higher dwell time in the field study. Table one shows that there is more traffic in the field study than in the simulator study, which could also be a reason for the difference between the dwell time. The difference for dwell time in AOI_E is 0,3%.

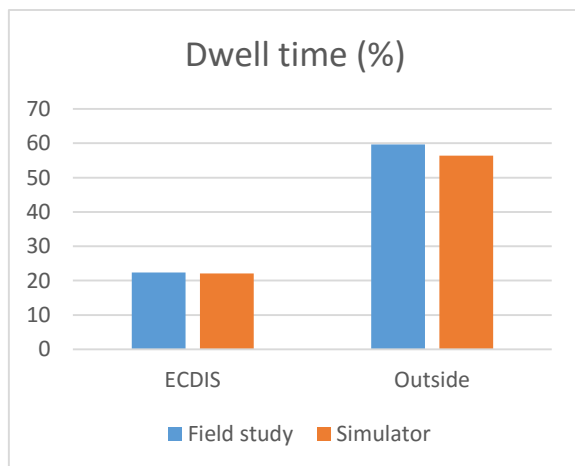


Figure 4: Comparison of average dwell time in AOIs.

KPI dwell time indicates that the visual attention of the navigator when it comes to the defined AOIs is coinciding.

Military high-speed navigation in inshore waters of the Norwegian coastline is conducted in a navigation team (10). Two persons conduct the navigation, and this is due to the high workload of the navigator, and the vessel speed. The collected data show that the navigator uses 60% of the time

looking outside the window, correlating the vessels position with the surroundings and comparing this with the information presented in the INS primarily in the ECDIS.

⁴ P-value of 0,62 ignores outlier in Field Study Participant 4 due to software problem.

⁵ P-value of 0,19 ignores outlier in Field Study Participant 7 due to software problem.

When analysing dwell rate, which is the number of entries into a specific area of interest per minute, the findings supports the similarity between the field study and simulator study (9).

3.2 Average fixation time

Figure 5 illustrates a higher average fixation time in the simulator study compared to the field study. In AOI_E the difference is 19 ms, and in AOI_O the difference is 86 ms.

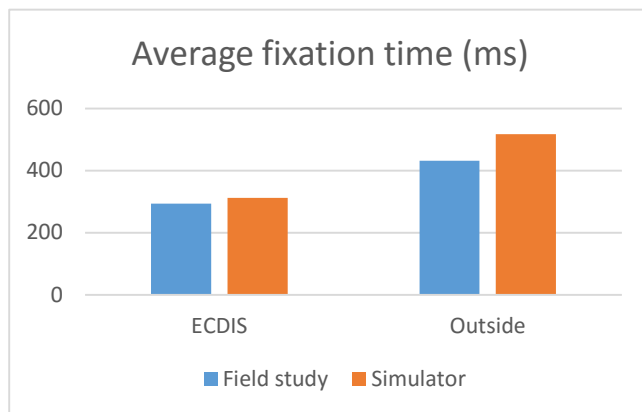


Figure 5: Comparison of average fixation time in AOIs.

The average fixation time for the eight trials indicates that the participants has a longer average fixation time in simulator compared to the field study for AOI Outside. This finding could indicate that a navigation task in the simulator is associated with a deeper and more effortful cognitive process (8, 9). One possible reason for this could be that the visual display in the simulator and the

simulator database is more difficult to cognitively process than the real life image of the surroundings of the ship. The navigator is accustomed to the real life image presented in 3D with high definition, and good colour contrasts. The virtual reality, presented on the projectors in the simulator, is in 2D with lower definition and less colour contrast. This could contribute to the more demanding cognitive process in the simulator study compared to the field study. Note also that the navigator conducts most training on board while in operation, and is more accustomed with reality. This finding suggest continuous work on updating details and improving resolution of simulator database would improve realism in simulator navigation training. Further, this would decrease the cognitive strain on the navigators.

3.3 Fixation rate

Figure 6 illustrates a 13 % higher fixation rate in both AOIs in the field study compared to the simulator study. Comparison of the fixation count in the AOIs ignores fixation duration. Due to the difference in trial time, fixation rate is selected.

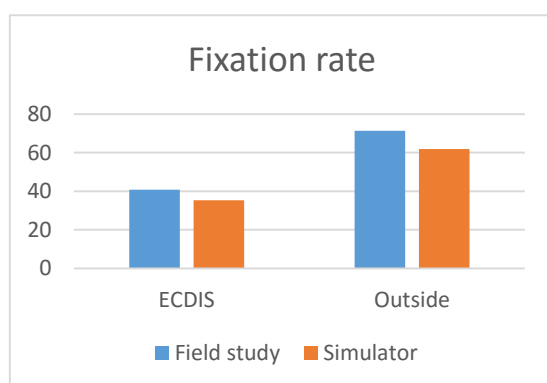


Figure 6: Comparison of fixation rate in AOIs.

The analysis indicates that there is a lower fixation rate in the simulator study compared with the field study. Fixation rate is found to be negatively correlated with task difficulty (11). This indicates that interpreting the visual picture in the simulator is more difficult than in the field study. This supports the finding that the mental workload, due to a more demanding cognitive process of processing the simulator image, is higher in the simulator (12).

4. Conclusion

The aim of this article was to present a comparative study of bridge navigation and simulator training to evaluate possible disparities between bridge simulator training and on board training. Findings indicate that the use of a 1:1 bridge simulator is efficient when it comes to navigation training, and provides the same training outcome as on board. It has been identified that the average fixation time

in AOI₀ is higher in the simulator. A lower fixation rate also indicate that the use of bridge simulators involves a more demanding cognitive process leading to a higher mental workload for the navigator. Instructors should consider this when designing simulator navigation scenarios. A higher degree of details in the simulator database and a higher simulator display resolution could compensate for this distinction.

It has also been identified that use of ETG hampers the detection of dark object during twilight, further research with the use of ETG in twilight must consider this.

4.1 Future work

The current data set is not 100% coinciding when it comes to variables outlined in table 1, and developing a new data set without these limitations could substantiate the findings in this article. The current dataset indicates that further elaboration on the time distribution of the navigators' visual attention is of interest.

5. Acknowledgement

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6. Reference

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