Quantitative Gaze Similarity Analysis for Operation-based Maritime Studies: A Conceptual Approach

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Abstract. Video-based eye-tracking technology has demonstrated promising potential for quantitatively assessing the mental states of maritime professionals, particularly perceptual performance related to situational awareness—a critical competency for operators of both conventional and crewless ships. Quantitative evaluation of perception can support the enhancement of training curricula for conventional operators and accelerate the development of effective training frameworks for remote operations of unmanned ships. One approach to evaluating perceptual performance is gaze similarity analysis; however, existing quantitative methods for operation-based experimental settings incorporate subjective elements, which may limit analytical accuracy and reproducibility. To address this limitation, this study proposes a conceptual, quantitative gaze similarity analysis method that does not rely on subjective judgment. The method is demonstrated through an experiment involving simulated remote ship operations. In the experiment, a participant wearing a mobile eye-tracker monitored two navigational scenarios: southbound and northbound passages through the Uraga Channel traffic route. Fixation data obtained from both scenarios were analyzed using the proposed method. The results indicate that gaze similarity can be quantitatively assessed in operation-based experimental settings using data derived directly from operational tasks, thereby providing an alternative framework that complements existing approaches for evaluating perceptual performance among maritime professionals.

Keywords: eye movement, gaze movement, image processing, seafarer, shore-based operator

1. Introduction

Situational awareness (SA) has been widely recognized as a critical non-technical skill for maritime professionals. Numerous studies investigating the competencies required of future seafarers — whether operating onboard conventional vessels or from shore-based remote control stations — consistently identify the ability to maintain adequate situational awareness as essential for safe and effective operations (Bogusławski et al., 2022; Chan, Norman, et al., 2022; Chan et al., 2025; Chan, Pazouki, & Norman, 2022; Kim & Mallam, 2020; Yoshida et al., 2020). As maritime operations become increasingly complex, particularly with the emergence of unmanned and remotely operated vessels, the importance of understanding and assessing situational awareness continues to grow.

Reflecting this importance, a growing body of literature has examined situational awareness among maritime professionals (Chan, Norman, et al., 2022; Chan, Pazouki, & Norman, 2022; Palbar Misas et al., 2024; Veitch et al., 2024). In parallel with these efforts, eye-tracking technology has been increasingly adopted as a means of investigating the cognitive states of maritime professionals (Kamarumtham et al., 2026; Martinez-Marquez et al., 2021). By capturing gaze behavior, eye-tracking provides quantitative insight into perceptual processes, which constitute one of the fundamental building blocks of situational awareness during navigation and operation tasks.

Building on the use of eye-tracking to investigate perceptual processes, several studies in the maritime domain have explored quantitative methods for analyzing gaze behavior. These studies generally assess novice operators' performance by comparing their gaze patterns with those of experts (Atik, 2020; Atik & Arslan, 2019; Godwin et al., 2013; Kamarumtham & Murai, 2025; Li et al., 2020; Mao et al., 2019; Muczynski et al., 2013). Nonetheless, to date, only a limited number of studies have specifically addressed the development of gaze similarity analysis methods in the maritime context, including two focused on operation-based experimental settings (Li et al., 2020; Mao et al., 2019) and one focused on screen-based experimental settings (Kamarumtham & Murai, 2025). Although participant numbers in these studies remain limited, their findings indicate promising potential for enhancing training curricula for maritime operators working on both conventional and unmanned vessels.

Despite this progress, methodological limitations remain. In particular, the gaze similarity analysis methods developed for operation-based experimental settings incorporate subjective elements in their analytical procedures (Li et al., 2020; Mao et al., 2019). While these approaches represent an important step forward in the quantitative assessment of perceptual performance, the inclusion of subjective components may limit analytical accuracy, reproducibility, and broader applicability across different operational contexts. Moreover, another existing gaze similarity analysis was specifically designed for screen-based experimental settings; thus, it is unsuitable for operation-based experimental settings (Kamarumtham & Murai, 2025). Additionally, Martinez-Marquez et al. (2021) reported that although eye tracking has been widely applied in aviation and construction research, no gaze similarity analysis methods had been introduced in either field.

In response to this limitation, the objective of the present study is to introduce and demonstrate a conceptual gaze similarity analysis method for operation-based experimental settings that does not rely on subjective elements. By adopting a fully quantitative approach grounded in operational data, this study aims to provide an alternative methodological framework for assessing gaze similarity and perceptual performance among maritime professionals.

2. Methodology

2.1 Operation-based & Screen-based Experimental Settings

Eye-tracking studies in the maritime field can be broadly grouped into two categories based on the experimental setups: (1) operation-based and (2) screen-based. Operation-based setup refers to experimental settings where participants perform tasks in full-mission simulators, actual ships, or environments that closely resemble real-world operational settings. This setup commonly uses mobile eye trackers, eye-tracking devices that are worn by users, allowing the users to move freely within the experimental settings. Alternatively, screen-based setup refers to experimental settings where participants perform tasks presented via a single-screen interface, commonly in controlled laboratory settings. This setup commonly uses remote eye trackers, which do not require physical attachment to users and allow them to interact with digital interfaces more naturally. Table 1 summarizes the advantages and limitations of each setting. As mentioned in the previous chapter, this study will introduce a gaze similarity analysis method designed for operation-based experimental settings.

Table 1. Advantages and Limitations of Operation-based and Screen-based Experimental Settings.

Operation-based Experimental Settings	Screen-based Experimental Settings
Advantages - Higher ecological validity and more realistic operator behavior representation. - Better reflection of workload and situational awareness in real operations.	**Advantages** - Simpler and more controllable experimental setup. - Easier and less time-consuming data collection and analysis. - Higher experimental reproducibility.
Limitations - More complex and resource-intensive experimental setup. - More complicated and time-consuming data collection and analysis.	**Limitations** - Lower ecological validity. - Limited representation of real operational behavior and decision-making.

2.2 Eye-tracking Technology

In this study, a mobile eye tracker, EMR-9, was used (see Figure 1). The eye tracker was selected because it supports gaze recording in dynamic operational environments, which is a fundamental requirement for operation-based eye-tracking studies. As the primary objective of this study is to introduce and demonstrate a conceptual framework for gaze similarity analysis, priority was given to obtaining sufficient gaze data while maintaining a manageable data analysis process when configuring the system settings for the eye tracker. Table 2 summarizes the settings used in this study. To analyse

Figure 1. EMR-9
(Left: Cap-type, Middle: Glasses-type, Right:

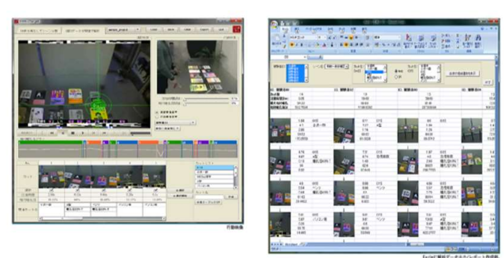

Figure 2. EMR-dTarget
(Left: Eye Mark Recording, Right: Excel Ouput)

the participant's fixation behavior, the accompanying analysis software, EMR-dTarget, was used (see Figure 2).

Table 2. EMR-9 eye-tracking system settings

System Type	☐ Cap	☑ Glasses		
Sampling	☑ 60 Hz	☐ 120 Hz	☐ 240 Hz	
Lens	☑ 44°	☐ 62°	☐ 92°	☐ 121°
Algorithm (Eye Mark Detection Method)	☑ Standard	☐ Pupil	☐ Purkinje	

Detailed explanations of these and other parameters can be found in the eye tracker's manuals (nac Image Technology, 2009, 2011)

2.3 Experimental Settings

To demonstrate the feasibility of the proposed conceptual method, at least two sets of fixation data are required for comparison. Accordingly, this study conducted a small-scale illustrative experiment involving a single participant performing two simulated remote ship operations. The participant was a final-year undergraduate student at the Tokyo University of Marine Science and Technology, majoring in Maritime Systems Engineering, and had completed two months of onboard training as a deck cadet.

The simulated remote ship operations comprised two navigational scenarios—southbound and northbound transits—along the Uraga Channel traffic route. In the southbound scenario, the ship transited the traffic route from point A to point B, whereas in the northbound scenario, the ship transited from point C to point D (see Figure 3), and both operations lasted 29 minutes.

The participant was provided with three monitors displaying ECDIS, bridge view, and RADAR information (see Figure 4). The instruction given to the participant was as follows: "Please imagine yourself as the officer in charge, performing monitoring duties in a remote ship operation".

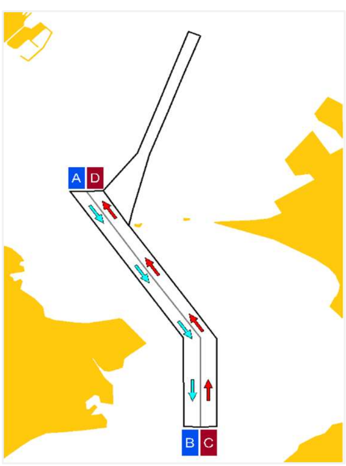

Figure 3. Southbound and Northbound Transits along the Uraga Channel Traffic Route

Figure 4. Experimental Setup of the Simulated Remote Ship Operations

2.4 Gaze Similarity Analysis

To measure the similarity between the two sets of fixation data obtained from the southbound and northbound operations, the monitors showing the ECDIS, bridge view, and RADAR were assigned as areas of interest (AOIs). Each AOI was subdivided into a grid of cells (see Figure 5), with each cell measuring 120 × 120 pixels. Given that the resolution of each AOI was 1920 × 1080 pixels, each AOI comprised 144 cells.

ECDIS	Bridge View	RADAR

Figure 1. AOIs (Upper) and Gridded AOIs (Lower)

While Holmqvist and Andersson (2011) have defined fixations using thresholds ranging from 0.2 to 0.4 s and above, a threshold of 0.4 s was adopted for two reasons: (1) the data analysis process was time-consuming, and (2) the primary objective of this study was to demonstrate the feasibility of the proposed conceptual method rather than to determine optimal parameter settings.

Next, the total fixation duration within each cell was calculated. This process resulted in two sets of three two-dimensional arrays, each representing the spatial distribution of fixation durations across the AOIs. Subsequently, each two-dimensional array was converted into a one-dimensional array, and the resulting arrays were concatenated to form a single one-dimensional array for each operation. Consequently, two one-dimensional arrays were obtained, representing the fixation data from the southbound and northbound operations. The similarity between these two fixation datasets was then quantified using three gaze similarity indices: (1) Spatial Similarity Index (SSI), (2) Spatial–Temporal Similarity Index (STSI), and (3) High-Salience Similarity Index (HSSI).

2.5 Gaze Similarity Indices

a. Spatial Similarity Index (SSI)

SSI quantifies similarity between two fixation datasets based solely on the spatial distribution of fixations, independent of fixation duration. This is achieved by converting all cells with nonzero values to 1 and assigning 0 otherwise, thereby retaining only spatial fixation information. The SSI between the resulting binary datasets is computed using the Dice coefficient (1), yielding similarity values ranging from 0 (no overlap) to 1 (perfect overlap).

b. Spatial-Temporal Similarity Index (STSI)

STSI quantifies similarity between two fixation datasets by considering both fixation areas and their associated durations. This is achieved by retaining the original cell values, which represent accumulated fixation duration. The STSI between the two datasets is computed using cosine similarity (2), producing values between 0 (no similarity) and 1 (perfect similarity).

c. High-Salience Similarity Index (HSSI)

HSSI quantifies similarity between two fixation datasets by focusing on fixation areas with the highest salience. Specifically, the original values of cells corresponding to the top 10% of fixation durations are retained, while all values in the lower 90% are set to zero. The HSSI of the resulting high-salience fixation datasets is computed using cosine similarity (2). As with STSI, HSSI values range from 0 (no match) to 1 (perfect match).

$$Dice\ Coefficient = \frac{2\sum_{i=1}^{n} X_i Y_i}{\sum_{i=1}^{n} X_i + \sum_{i=1}^{n} Y_i} \quad (1)$$

$$Cosine\ Similarity = \frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2} \cdot \sqrt{\sum_{i=1}^{n} Y_i^2}} \quad (2)$$

Where:

$X_i = value\ of\ the\ i-th\ cell\ in\ the\ gaze\ pattern\ for\ Southbound\ Operation$

$Y_i = value\ of\ the\ i-th\ cell\ in\ the\ gaze\ pattern\ for\ Northbound\ Operation.$

3. Results

3.1 Fixation Areas and Durations

a. Southbound Operation

Figures 6, 7, and 8 show the participants' fixation areas and durations (in seconds) during the southbound operation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1															0.74		1
2						0.45		1.37	3.09	0.82					0.66	3.97	2
3						4.6	28.5	30.11	21.09							4.24	3
4					3.02	4.85	21.34	7.98	16.89			0.89					4
5						2.25	9.97	19.99	57.83	8.6							5
6							0.98	13.21	23.61	5.54	1.19					0.64	6
7							0.52	2.17	5.61		1.58	8.03		0.8			7
8									3.6	3.65	3.5						8
9																	9
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Figure 2. Participant's Fixation Data for ECDIS during Southbound Operation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1		0.43					2.07	1.89	5.02	6.66	1.98	2.01	4.51	2.42	0.73	0.49	1
2			1.19	3.59	0.86	3.17	5.16	13.78	13.18	11.25	4.46	3.46	4.47	1.09	3.18		2
3				4.98	5.11	5.5	16.18	12.95	25.29	18.04	17.65	6.71	3.56	4.55		1.05	3
4	1.72	1.92	2.95	5.26	11.01	13.45	28.39	30.76	23.1	16.31	14.78	14.82	3.13	4.52	2.39		4
5	1.44	1.61	1.95	4.72	10.31	8.44	29.79	31.65	34.66	22.87	11.53	5.39	3.82	1.91	1.91		5
6	0.9	1.75	2.28	1.8	1.78	10.15	20.68	10.86	15.09	7.17		4.52	4.52	2.08			6
7			2.03	2.36	0.88	1.08	7.86	4.62	8.09	6.81	6.32	1.88	1.95	0.57	0.52		7
8					0.55		0.55		1.9	7.32				1.53			8
9								0.66	2.29								9
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Figure 3. Participant's Fixation Data for Bridge View during Southbound Operation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	0.48				0.64												1
2												1.33	1.86				2
3				1.99	6.38	5.61	0.62	0.4									3
4	1.16	0.84		1.19	51.37	17.07	1.33						2.77				4
5					1.79	29.52	19.46	9.25					1.25	1.01			5
6	0.73		16.78			17.25	34.82	2.82				6.26	3.22				6
7					10.8	10.11		3.96					0.91			1.87	7
8				1.25					3.08			1.33			5.54	1.33	8
9									1.42	2.92							9
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Figure 4. Participant's Fixation Data for RADAR during Southbound Operation

b. Northbound Operation

Figures 9, 10, and 11 show the participants' fixation areas and durations (in seconds) during the southbound operation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1						1.72									0.9	2.24	1
2					3.85		13.3	1.61				0.76		0.48	1.14	1.19	2
3							2.53	17.19	25.08			0.7	3.27	3.47	1.19	1.04	3
4					2.32	11.04	5.58	22.1	2.08	3.87		1.59		1.63	2.91		4
5				0.85		7.9	22.41	15.24	16.46	0.92		0.51	0.57	0.76	1.59	1.27	5
6				0.52		1.63	7	10.87	8.8	30.33		4.19		7.31	0.54	0.61	6
7							4.73	3.46	0.97	1.1		1.03	2.31		2.9		7
8								2.12						2.3	1.48	8.83	8
9										1					1.34		9
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Figure 5. Participant's Fixation Data for ECDIS during Northbound Operation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1			0.62		0.44	0.44	4.59	0.58	2.25	4.63	8.86	1.79	2.69				1
2		3.52	2.83	2.38	4.95	1.1	1.46	2.92	9.73	3.98	1.11	1.99	1.42	1.7			2
3	1.08	6.63	2.77	9.66	5.98	11.66	9.96	12.15	9.08	14.1	5.06	2.77	3.23		1.77	0.97	3
4		0.99	10.06	14.77	6.23	5.74	15.4	14.86	11.04	14.47	10.47	8.49	1.38	3.79	1.09	1.71	4
5	0.64		6.12	3.76	5.01	8.93	8.79	12.82	12.71	23.32	12	5.03	6.38	0.53	0.92	0.42	5
6	5.54	1.69	3.89	6.6	22.22	2.43	4.8	11.81	13.94	10.57	7.67	5.96	3.89		1.45	0.43	6
7	0.66	2.88		6.42	6.63	4.72	5.71	5.81	11.78	2.22	2.34	1.28	1.66	1.06		1.48	7
8		0.63		2.03	1.88	0.8	8.76		1.87	1.73	0.88		0.8		0.4		8
9		1.07						0.58	1.05		1.12						9
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Figure 6. Participant's Fixation Data for Bridge View during Northbound Operation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	1.25	0.54															1
2		0.57		0.48													2
3				4.23	2.3	7.04	0.42	0.8									3
4	3.5		0.91		5.23	4.16	3.16										4
5				2.3		4.22	3.16						0.75				5
6	1.96		0.75		2.6												6
7																	7
8		1.29					0.6						0.63				8
9																	9
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Figure 7. Participant's Fixation Data for RADAR during Northbound Operation

3.2 SSI, STSI, and HSSI

Table 3 presents the percentages of SSI, STSI, and HSSI for the two fixation datasets.

Table 3. Similarities between participant's fixation data during southbound and northbound operations

Gaze Similarity Indices	**Similarity Percentages**
Spatial Similarity Index (SSI)	66.3
Spatial-Temporal Similarity Index (STSI)	61.0
High-Salience Similarity Index (HSSI)	62.3

4. Discussion

The SSI, STSI, and HSSI values obtained for the two gaze datasets were 66.3%, 61.0%, and 62.3%, respectively. Given that both datasets were generated by the same participant performing similar monitoring tasks, higher similarity scores might initially be expected. However, several operational and human-related factors may explain the observed differences in gaze behavior between the two operations.

First, although both operations were conducted in the same geographical area, the surrounding traffic conditions differed in terms of traffic density and vessel approach direction. Variations in traffic situations are likely to influence visual attention allocation, particularly toward information-intensive displays such as the ECDIS and RADAR. Consequently, differences in traffic scenarios may have resulted in shifts in fixation distribution across these interfaces. Second, the nature of the monitoring task itself may have influenced gaze behavior. Monitoring tasks are relatively passive and may induce reduced vigilance over time. As the experiment involved consecutive operations, the participant may have experienced a decline in attention or focus during the second operation, leading to variations in fixation patterns. Finally, a learning or adaptation effect may also account for the observed discrepancy in gaze similarity. The participant may have required an initial period to become familiar with the simulated operational environment and display layout, resulting in differences in visual scanning strategies between the first and second operations.

Importantly, the purpose of this study is not primarily to establish empirical findings regarding operator performance or human behavior under specific maritime conditions. Rather, the main contribution of this study is methodological: to demonstrate that the proposed conceptual framework can quantitatively evaluate gaze similarity in operation-based experimental settings and produce interpretable outputs linked to operational behavior. In other words, the obtained similarity values should not be interpreted merely as numerical indicators, but as quantitative representations of underlying differences in visual attention allocation and scanning strategies.

From this perspective, the moderate similarity scores observed in this study are meaningful because the proposed framework generated quantitative outputs that correspond plausibly with identifiable operational and cognitive factors, such as traffic conditions, vigilance changes, and adaptation effects. The ability to relate the resulting similarity indices to interpretable behavioral and contextual differences suggests that the framework can support not only quantitative comparison of gaze data, but also analytical interpretation of why particular similarity values emerge.

Taken together, these findings support the feasibility of the proposed framework as an alternative quantitative approach for gaze similarity analysis in operation-based experimental settings. The study therefore serves primarily as a proof-of-concept demonstration of the framework's applicability and interpretability, rather than as a definitive empirical investigation of maritime operator behavior.

5. Conclusion

This study introduced and demonstrated a conceptual, quantitative gaze similarity analysis method for operation-based experimental settings. The results indicate that the proposed method has potential as an effective alternative framework for quantitatively assessing gaze similarity without reliance on subjective elements. By deriving similarity measures directly from operational data, the method offers a structured approach to evaluating perceptual performance in maritime contexts. Nevertheless, one notable limitation of the proposed method is that the data analysis process is time-consuming, which may restrict its applicability in large-scale studies. The integration of deep learning–based techniques presents a promising direction for overcoming this limitation by automating and accelerating key stages of the analysis pipeline.

Future work may focus on incorporating deep learning approaches to reduce analysis time and improve scalability. Additional efforts should also consider systematic adjustments of experimental parameters, including eye-tracker settings, fixation duration thresholds, and the number and size of spatial cells, to examine their influence on gaze similarity outcomes. Validation of the proposed similarity indices against operator performance, situational awareness, and expert gaze behaviour should also be investigated to further evaluate the analytical effectiveness and practical relevance of the framework. In addition, future studies should aim to establish clearer interpretative benchmarks for similarity values by comparing results across different operational conditions and participant groups. Furthermore, expanding the sample size, diversifying participant backgrounds, and including a wider range of operational scenarios will be essential for evaluating the generalizability and practical applicability of the proposed method in maritime training and operational environments.

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References

Atik, O. (2020). Eye Tracking for Assessment of Situational Awareness in Bridge Resource Management Training. *Journal of Eye Movement Research*, *12*(3). https://doi.org/10.16910/jemr.12.3.7

Atik, O., & Arslan, O. (2019). Use of Eye Tracking for Assessment of Electronic Navigation Competency in Maritime Training. *J Eye Mov Res*, *12*(3). https://doi.org/10.16910/jemr.12.3.2

Bogusławski, K., Gil, M., Nasur, J., & Wróbel, K. (2022). Implications of autonomous shipping for maritime education and training: the cadet's perspective. *Maritime Economics & Logistics*, *24*(2), 327-343. https://doi.org/10.1057/s41278-022-00217-x

Chan, J. P., Norman, R., Pazouki, K., & Golightly, D. (2022). Autonomous maritime operations and the influence of situational awareness within maritime navigation [Article]. *WMU Journal of Maritime Affairs*, *21*(2), 121-140. https://doi.org/10.1007/s13437-022-00264-4

Chan, J. P., Pazouki, K., Norman, R., & Golightly, D. (2025). Investigating the Impact of Seafarer Training in the Autonomous Shipping Era. *Journal of Marine Science and Engineering*, *13*(4), 818. https://doi.org/10.3390/jmse13040818

Chan, J. P., Pazouki, K., & Norman, R. A. (2022). An experimental study into the fault recognition of onboard systems by navigational officers. *Journal of Marine Engineering & Technology*, *22*(2), 101-110. https://doi.org/10.1080/20464177.2022.2143312

Godwin, H. J., Hyde, S., Taunton, D., Calver, J., Blake, J. I. R., & Liversedge, S. P. (2013). The Influence of Expertise on Maritime Driving Behaviour. *Applied Cognitive Psychology*, *27*(4), 483-492. https://doi.org/10.1002/acp.2925

Holmqvist, K., & Andersson, R. (2011). *Eye Tracking: A Comprehensive Guide to Methods, Paradigms, and Measures*. OUP.

Kamarumtham, K. I., & Murai, K. (2025). A Conceptual Method for Assessing Seafarers' Perceptions: Video-based Gaze Similarity Analysis. *WMU Journal of Maritime Affairs*, A Conceptual Method for Assessing Seafarers' Perceptions: Video-based Gaze Similarity Analysis, https://doi.org/10.1007/s13437-025-00397-2

Kamarumtham, K. I., Win, T. K., Ishida, T., & Murai, K. (2026). Eye Tracking in Maritime Research: A Systematic Review. *Scientific Journal of Maritime Research [Pomorstvo]*, *40*, 124-139. https://doi.org/https://doi.org/10.31217/p.40.1.8

Kim, T.-e., & Mallam, S. (2020). A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations. *WMU Journal of Maritime Affairs*, *19*(2), 163-181. https://doi.org/10.1007/s13437-020-00203-1

Li, G., Mao, R., Hildre, H. P., & Zhang, H. (2020). Visual Attention Assessment for Expert-in-the-Loop Training in a Maritime Operation Simulator. *IEEE Transactions on Industrial Informatics*, *16*(1), 522-531. https://doi.org/10.1109/tii.2019.2945361

Mao, R., Li, G., Hildre, H. P., & Zhang, H. (2019). Analysis and Evaluation of Eye Behavior for Marine Operation Training - A Pilot Study. *Journal of Eye Movement Research*, *12*(3). https://doi.org/10.16910/jemr.12.3.6

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 (Basel)*, *21*(13), 4289. https://doi.org/10.3390/s21134289

Muczynski, B., Gucma, M., Bilewski, M., & Zalewski, P. (2013). Using eye tracking data for evaluation and improvement of training process on ship's navigational bridge simulator. *Scientific Journals Maritime University of Szczecin*, *33*, 75-78. https://doi.org/https://www.infona.pl/resource/bwmeta1.element.baztech-82002879-b757-43c7-8325-c187ae11d2e0/tab/summary

nac Image Technology, I. (2009). *NAC Eye Mark Recorder EMR-9 Quick Start Guide*. I. nac Image Technology. https://www.manualslib.com/manual/2941942/Nac-Emr-9.html

nac Image Technology, I. (2011). *EMR-9 User Manual (in Japanese)*. I. nac Image Technology. https://www.eyemark.jp/_userdata/pdf/EMR-9_manual.pdf

Palbar Misas, J. D., Hopcraft, R., Tam, K., & Jones, K. (2024). Future of maritime autonomy: cybersecurity, trust and mariner's situational awareness. *Journal of Marine Engineering & Technology*, *23*(3), 224-235. https://doi.org/10.1080/20464177.2024.2330176

Veitch, E., Alsos, O. A., Cheng, T., Senderud, K., & Utne, I. B. (2024). Human factor influences on supervisory control of remotely operated and autonomous vessels. *Ocean Engineering*, *299*. https://doi.org/10.1016/j.oceaneng.2024.117257

Yoshida, M., Shimizu, E., Sugomori, M., & Umeda, A. (2020). Regulatory Requirements on the Competence of Remote Operator in Maritime Autonomous Surface Ship: Situation Awareness, Ship Sense and Goal-Based Gap Analysis. *Applied Sciences*, *10*(23). https://doi.org/10.3390/app10238751