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A Delphi Study to Formalize Domain Knowledge on Maritime Collision Avoidance and Inform Training.

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Abstract:

Maintaining effective situation awareness (SA) is a key facet that experienced Officers of the Watch (OOWs) build to practice safe collision avoidance and sound Bridge Resource Management (BRM). Novice OOWs lack the experience to efficiently use sources of information on the bridge to build and maintain SA. This research takes a human centred approach though a Delphi study to answer the following question: Can consensus be reached between domain experts to create a training tool to increase SA for collision avoidance amongst new watchkeeping officers? The study is founded in Endsley's model of SA and the COLREGs. The researchers will take a mixed methods approach and use a series of surveys administered through Qualtrics to elicit opinions from experienced seafarers as they relate to collision avoidance, SA information requirements, sources of information from bridge equipment, and BRM. The goal is to create a generalizable sequence for efficiently collecting information, supported by a consensus from the experts. In this paper the preliminary insights from the first round of the survey are discussed and the details for how subsequent survey rounds will be designed and administered is explained. If consensus is reached the resulting procedural training tool will be member checked for validation. It is anticipated that this research could improve OOW training programs by reducing the time required for novice OOWs to gain experience in SA for collision avoidance.

Keywords: Collision Avoidance; Maritime Educational Training, Bridge Resource Management, Situation Awareness.

1. Introduction

As the world rebounds from the COVID-19 pandemic, the demand is expected to climb for maritime shipping and subsequently trained seafarers, despite the already strained number of trained Officers of the Watch (OOWs) (UNCTAD, 2021; WMU, 2019). Compounding this problem, training a new OOW can take between 12 and 36 months (Canadian Coast Guard, 2022). Further, research has shown that novice OOWs when compared to experienced OOWs lack the same ability to exercise effective Bridge Resource Management (BRM) and skill to build and maintain good situation awareness (SA) (Atik, 2019; Chauvin et al., 2008). This distinction in experience is important as effective BRM and SA are key to maritime safety; poor SA can lead to an increase in human error and maritime accidents (Atik, 2019). The objective of the research is to gather domain knowledge from maritime subject matter experts (SMEs) on how they establish good SA for collision avoidance with the purpose of formalizing these mental models into procedural training tools such as a checklist.

Central to this research is Endsley's (1995) model of SA which is comprised of three levels: "perception of elements in the current situation, comprehension of those elements in the current situation, and projection of those elements into future states" (Endsley, 1995, p 36). This model designates the perception of the situation as level 1 SA, the comprehension of the situation as level 2 SA, and the projection into a future state as level 3 SA. To illustrate this model using a practical maritime example, consider the International Regulations for the Prevention of Collisions at Sea (COLREGs) rule 15 where two vessels that find themselves in a crossing situation (COLREGs, 2003). In this illustration, the OOWs in each vessel would have to perceive the elements in the current situation (level 1 SA) e.g., pay attention to their own position, course, and speed, as well as the relative location of the other vessel. The OOWs would also need to comprehend the elements in the current

situation (level 2 SA) e.g., understand how their own position, course, and speed relate to the other vessel's position course and speed and the COLREGs rule that governs their interaction. The OOWs would finally need to project those elements into a future state (level 3 SA) e.g., recognize the expected actions of the stand-on vessel and the give way vessel and anticipate the approximate ranges where their decision/action is expected to take place. Although the example provides a linear sequence this is not necessarily the case in how SMEs establish good SA. Further, Endsley's model is non-linear, and the OOWs in the above situation may only need select pieces of information from levels 1, 2, and 3 to act in this situation.

2. Research Objectives and Methods

In this research we used a Delphi study to understand maritime operations and report the findings to answer the question: Can consensus be reached between domain experts to create a procedure to increase situational awareness for collision avoidance amongst new watchkeeping officers? To inform this research question, we are conducting a series of surveys. The surveys are designed to ask maritime domain experts their opinions on collision avoidance, best practices in use of bridge equipment, and bridge resource management. The surveys are administered through the Qualtrics™ web application and analyzed through NVivo™ software. Consensus will be measured quantitatively through statistical analysis while the respondents' goals and opinions will be elicited and recorded qualitatively to identify recurring themes related to safe maritime navigation through effective collision avoidance.

2.1 Intended Population

The population sought as participants are Canadian maritime SMEs with at least 5 years' experience as an OOW or Deck Watch Officer. The inclusion criteria included Master Mariners, harbour pilots, and maritime course instructors at nautical institutes, as well as other mariners from industry. We restricted the population to Canadian seafarers for ease of recruitment and commonality of practice; however, the results may be relevant to the broader maritime community as the basis of collision avoidance is in the COLREGs.

2.2 Delphi Methods

A flow chart of the anticipated sequence of the Delphi survey rounds is depicted below in Figure 1. The participants' responses will be tracked through the rounds to link changes in their opinions when presented with other participants' aggregated opinions from round to round.

It is anticipated that the study may involve upwards of four rounds of surveys, however the objective of a Delphi study is to assess consensus or stability in the responses, not to complete a certain number of rounds. It is possible that consensus could be generated in three rounds, or it may require five rounds. If consensus cannot be achieved, then emphasis will be on the stability of responses between the rounds (von der Gracht, 2012). The lack of consensus on a topic can be as profound as consensus.

2.3 Survey Question Design

The initial round of the survey will collect demographic information and gather the SMEs opinions of goals, factors, and information requirements related to SA for collision avoidance. Sample questions from the first round include "What does risk of collision mean to you?", "How do you determine if a risk of collision exists?", "What factors influence the methods in determining a risk of collision?", "What does BRM mean to you?" and "What advice would impart to a new watchkeeping officer?" The survey will also ask questions on the utility and reliability of bridge equipment, specifically Electronic Chart Display Information System (ECDIS), Automatic Identification System (AIS), radar and Automatic Radar Plotting Aid (ARPA), and radio-telephone information, including Vessel Traffic Management Systems (VTMS).

As part of the Delphi process, the results of each round will inform the development of later rounds (e.g., each round of questions will build off the participants' responses). The second round will refine the respondents' opinions of specific collision avoidance goals by presenting aggregated thematic responses from round one to the participants. Participants will be asked if they have a preferred mental model or sequence for collecting information on the bridge to support SA and collision avoidance. Round three is dependent on the results of round two and is planned present a sequence for information collection to support collision avoidance for the group's feedback. Consequently, round four will likely be a confirmation of consensus in the responses.

Participants' responses will be tracked throughout the rounds of surveys to monitor for changing opinions through the process. Once a list of key goals and processes is generated and agreed upon by consensus, the list will then be member checked by a separate panel of SMEs. Member checking is a tested method of validating qualitative research and is used in other research on SA in the maritime sector (Braun and Clark, 2013; Creswell, 2014; Morse, 2015; Sharma et al, 2019).

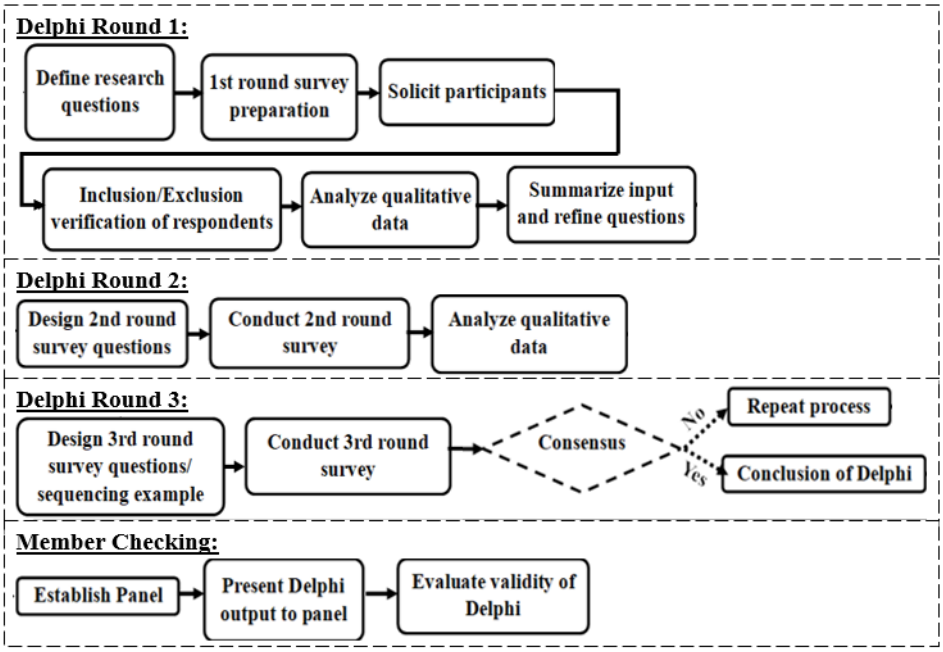


Figure 1 - Flowchart of Delphi method for study (adapted from Kim and Mallam, 2020).

3. Preliminary Findings

3.1 Participants

Recruitment for participants commenced in March 2023. Solicitation took place by word of mouth within the Canadian seafarer community and was aided by social media announcements by the Master Mariners Association of Canada and the Center for Marine Simulation at the Marine Institute of Memorial University of Newfoundland. The recruitment information was also shared peer-to-peer within the Shipping Federation of Canada and the Canadian Pilotage Association. The first round of the survey was closed in April 2023 and resulted in 17 respondents who met the inclusion criteria of the study. These respondents will be invited to participate in subsequent rounds of the Delphi process. A summary of the demographic statistics is included in Table 1. In total,137 initial responses were recorded however 120 were excluded for not meeting the inclusion criteria or based on fraud/bot detection.

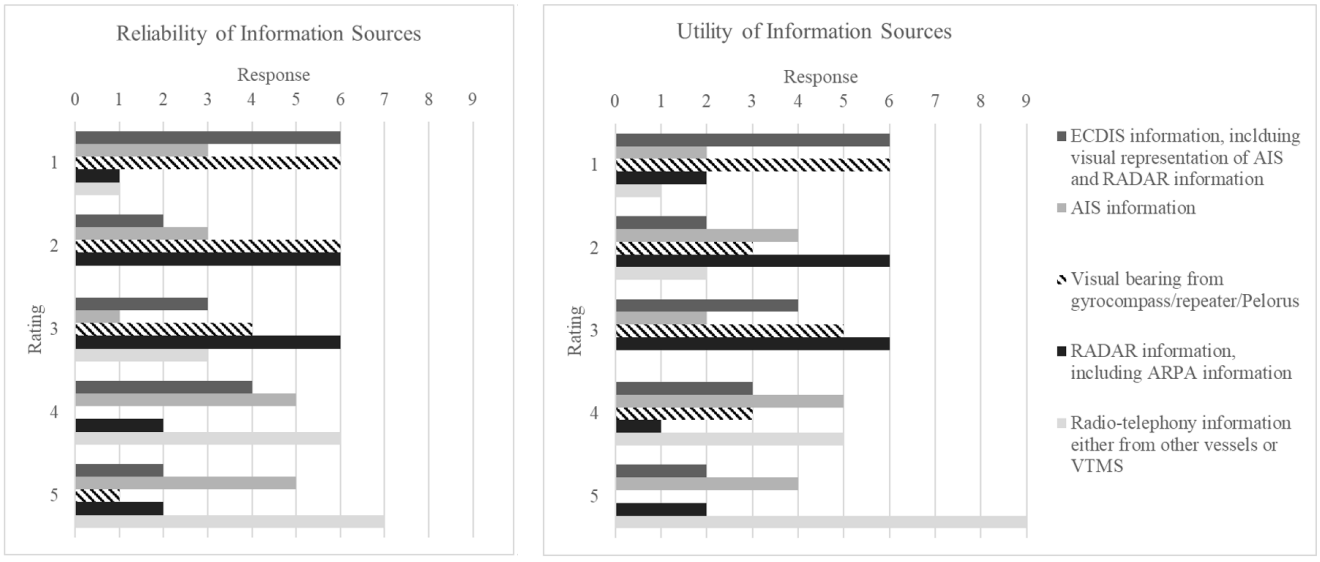
3.2 Initial Responses from First Round

Participants were asked to describe what 'Risk of Collision' meant to them and if there was a specific Closest Point of Approach (CPA) that they considered to have inherent risk of collision. Then, the subsequent questions used a storyboard to describe a scenario at sea where the participant would be encouraged to elaborate on their process for collecting information and describe factors affecting their process and their information requirements to decide to act to avoid collision. These questions were developed to link the language of the COLREGs and their interpretation with the industry standard *A Guide to the Collision Avoidance Rules* (Cockroft and Lameijer, 2011). Additionally, the survey asked participants what BRM meant to them and asked them what advice they would impart to a new watchkeeping officer. These questions were designed to draw out any more information on their interpretation of BRM and collision avoidance practices while considering their interpretation of important knowledge to help a new watchkeeper succeed at sea. For this round of the survey, qualitative analysis is still underway through NVivo software.

Table 1 - Demographic statistics of the participants in the study

Criteria of classification	Statistics	Frequency	Percentage (%)
Age	20-30	3	17.6
	31-40	7	41.2
	41-50	5	29.4
	>50	2	11.8
Certificate of Competency (CoC)	Master Mariner	6	35.3
	Master 3000t (Near Coastal and Domestic)	3	17.6
	Master 500t (Near Coastal and Domestic)	3	17.6
	Chief Mate (Unlimited and Near Coastal)	2	11.8
	Watchkeeping Mate (Unlimited and Near Coastal)	1	5.9
	Fishing Master	2	11.8
Years experience at sea	5-10yrs	7	41.2
	11-15yrs	6	35.3
	>15yrs	4	23.5
Gender expression	Male	15	88.2
	Female	2	11.8

The survey also asked questions related to utility and reliability of bridge equipment, specifically ECDIS, AIS, radar and ARPA, and radio-telephone information, including VTMS. The quantitative responses regarding perceived utility and reliability of bridge equipment as potential sources of information were available for reporting. Figure 2 shows the participants ranking of the sources of information related to their overall reliability (Figure 2.a) and utility (Figure 2.b), while table 2 shows the descriptive statistics of the responses for reliability (Table 2) and utility (Table 3).



(a) (b)

Figure 2. Ranking of information sources for (a) reliability and (b) utility.

Table 2. Descriptive statistics of ranking of reliability of information sources.

Ranking of Reliability	Mean	Median	Mode
Visual bearing from gyrocompass/ repeater/ Pelorus	2.00	2	2
ECDIS information, incl. visual representation of AIS and/or RADAR	2.56	2.5	1
RADAR information, including ARPA information	2.81	3	2
AIS information	3.50	4	5
Radio-telephony information from other vessels or from VTMS	4.13	4	4

Table 3. Descriptive Statistics of ranking of utility of information sources.

Ranking of Utility	Mean	Median	Mode
Visual bearing from gyrocompass/ repeater/ Pelorus	2.25	2	1
RADAR information, including ARPA information	2.56	2	2
ECDIS information, incl. visual representation of AIS and/or RADAR	2.63	3	1
AIS information	3.50	4	4
Radio-telephony information either from other vessels or from VTMS	4.06	4.5	5

Early results indicate that compared to the sources listed, the participants ranked ECDIS information to be the most reliable and visual bearings or observation being the most useful source of information. Radio-telephony information was considered to be the least reliable and least useful.

4. Future Surveys

As shown in flow chart of the Delphi process in Figure 1, results from initial round will inform subsequent rounds of surveys. Conceptually, the goal of the second round of the survey is to narrow the focus in on the processes and information requirements for collision avoidance to produce a sequence for information gathering to be evaluated in subsequent rounds. To support this goal, the intention is to ask the participants how they cross reference their sources of information. For example, participants listed ECDIS as the most useful and reliable source of information, but frequently discussed visual assessment or RADAR assessment. Follow-up questions would ask participants 1) how they compare information between the sources, 2) if they have instances where they would trust one over the other, and 3) if there are methods for optimizing cross-referencing. These questions will help to understand if SMEs employ redundancies in their information gathering. For example, do SMEs take advantage in the designed latency of ARPA plotting to check a visual bearing or ECDIS information. Further, the intention is to pose elaborative or probing questions to understand the generalizability of information gathering processes and how participants support the development of all three levels of SA in Endsley's model.

Consequently, the information collected in the second round of the survey will be used to hypothesize a sequence of gathering information for collision avoidance that is generalizable and useful. The sequence will be presented to the participants in round three to get their opinions on sequencing and on the benefits and drawbacks of that sequence. It is in this round and the next rounds where the measurement of consensus will take place. Since the participants in this round will have been with the study from the beginning, we believe that there will be sufficient context provided to the participants to have them comment and work towards consensus on the sequence.

If consensus can be achieved, or if the responses from the participants have been stabilized, the Delphi portion of the study will be concluded. The resulting product of the Delphi process in the way of a procedural training tool will then be member checked against a separate panel of SMEs who will provide validation and additional insight into the product (Braun and Clark, 2013; Creswell, 2014; Morse, 2015; Sharma et al, 2019). As the participants will be included in each round of the survey, potentially becoming a niche community of practice, their responses may become skewed. The purpose of the member checking SMEs is to confirm that the output of reality matches. Ideally, the SMEs will be checking a consensus-generated sequence for collecting information and establishing situation awareness in the context of collision avoidance. If consensus cannot be achieved, the areas of disagreement and stability will be presented to the panel for their comment.

5. Conclusion

This paper reports the preliminary results of a Delphi study. The participants consider ECDIS to be the most useful, but visual assessment to be the most reliable sources of information on the bridge. Conceptually, this makes sense. ECDIS provides a collated picture of many sources of information. Before ECDIS, the OOW had to create a mental model from a paper chart, radar, and other sources to get the same picture. It is important to also see that the participants still greatly value visual observation. Maintaining a lookout by sight, hearing, and all available means is still a tenant of collision avoidance (COLREGs, 2003). In subsequent rounds, we will work to see the why behind their initial responses. This knowledge will be important to the development of a potential sequenced checklist for gathering information and building SA. The resulting formalized processes

from this research have the potential to assist trainee OOWs in developing BRM schema for the efficient use of bridge equipment and lead to improved situation awareness. Consequently, the formalized processes could shortcut the time to expertise (Endsley, 2018) and be used to change OOW training programs to address the growing demand for seafarers.

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