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ROLE OF ECDIS TRAINING ON IMPROVING SITUATIONAL AWARENESS

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1 INTRODUCTION

August of 2018 marks the completion of the phasing in of ECDIS carriage requirements on SOLAS vessels engaged in international voyages. Additionally, more and more flag states are implementing similar ECDIS and/or ECS carriage requirements for vessels engaged in domestic trade within their territorial waters. Mariners are required to receive training in accordance with IMO Model Course 1.27 "Operational use of Electronic Chart Display and Information Systems" to serve as the Officer in Charge of the Navigation Watch (OICNW) on ECDIS equipped SOLAS vessels and some countries look for this same level of training to serve on their domestic fleet's vessels if they're equipped with either ECDIS or ECS. This is understandable considering the complexity of these navigation systems, yet even with this training requirement marine incident investigation organizations are still identifying improper use of ECDIS as a causal factor in groundings, which implies that rather than improving situational awareness these systems, at least in some cases, enable complacency (1; 2; 3; 4; 5). This paper describes the authors' efforts to gauge the effectiveness of ECDIS training through a statistical analysis of surveys completed by students before and after formal generic ECDIS training. The surveys are designed to measure the attitudes of the students towards the value of ECDIS in maintaining situational awareness and improving safety of navigation.

ECDIS is not only an e-navigation tool which can be used to satisfy the nautical chart carriage requirement of SOLAS, but can also totally change the way/method of performing marine navigation (6). ECDIS will be the focal point and main hub for Integrated Bridge Systems when configured as a Multifunction Display device where all voyage related data and

information from multiple sources such as propulsion, navigation control systems, steering systems, alarms, etc. can be accessed and used as a "decision support system" for both routine and emergency situations. (7)

1.1 Voyage planning

According to the IMO Guidelines for Voyage Planning (8)**,** "The development of a plan for voyage or passage, as well as the close and continuous monitoring of the vessel's progress and position during the execution of such a plan, are of essential importance for safety of life at sea, safety and efficiency of navigation and protection of the marine environment."

"Voyage and passage planning includes appraisal, i.e. gathering all information relevant to the contemplated voyage or passage; detailed planning of the whole voyage or passage from berth to berth, including those areas necessitating the presence of a pilot; execution of the plan; and the monitoring of the progress of the vessel in the implementation of the plan." In this paper these four stages of voyage planning are collectively referred to as voyage planning dimensions.

Clearly safety of navigation is fundamentally dependent upon the careful creation and verification of a detailed voyage plan. It follows that for the Officer In Charge of the Navigation Watch (OICNW) to navigate safely a thorough knowledge of the voyage plan is required, along with the ability to accurately interpret all aspects of the plan as displayed on the ECDIS.

1.2 Situational awareness

According to Endsley (9), Situational Awareness (SA) is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". SA is comprised of three dimensions: *Perception* - perceiving critical factors in the environment; *Comprehension* - understanding what those factors signify; and *Projection* - anticipating what will happen, or how the situation will evolve, in the near future. These levels are cumulative in nature as projection cannot occur without comprehension and comprehension cannot occur without perception.

Marine incident investigation reports reveal that loss of SA is directly responsible for 27 percent of marine incidents (10). ECDIS can play an important role for developing and maintaining a high level of situational awareness by supporting the four dimensions of voyage planning: appraisal, planning, execution and monitoring.

1.3 Relationship between cognitive hierarchy and situational awareness (SA)

For understanding SA, the difference between the terms data, information, knowledge and understanding has to be defined. According to International Association for Information and Data Quality (11), data is the raw material from which information is produced when it is put in a context that gives it meaning. Information is data in context, i.e., the meaning given to data or the interpretation of data based on its context; information is the data that have been shaped into a form that is meaningful and useful to human beings; knowledge is the understanding of the significance of information or information that is actionable. Knowledge contributes to understanding when experience, expertise and intuition are applied; a Cognitive Hierarchy Diagram can be used to describe this relationship (12), see Figure 1.

Endsley and Jones (13) suggest that the way in which information is presented by such systems influences SA by determining how much information can be acquired, how accurately

it can be interpreted and to what degree it is compatible with SA needs. Endsley and Jones draw a parallel between Endsley's three levels of SA and the "cognitive hierarchy" of data, information, knowledge, and understanding. Data correlated becomes information. Information converted into situational awareness becomes knowledge. Knowledge used to predict the consequences of actions leads to understanding. Endsley and Jones suggest that "knowledge" in this description equates to level 1 (Perception) SA and "understanding" equates to levels 2 (Comprehension) and 3 (Projection) SA. A higher level of SA requires relevant, accurate, and timely data and information which can be transformed into knowledge and understanding.

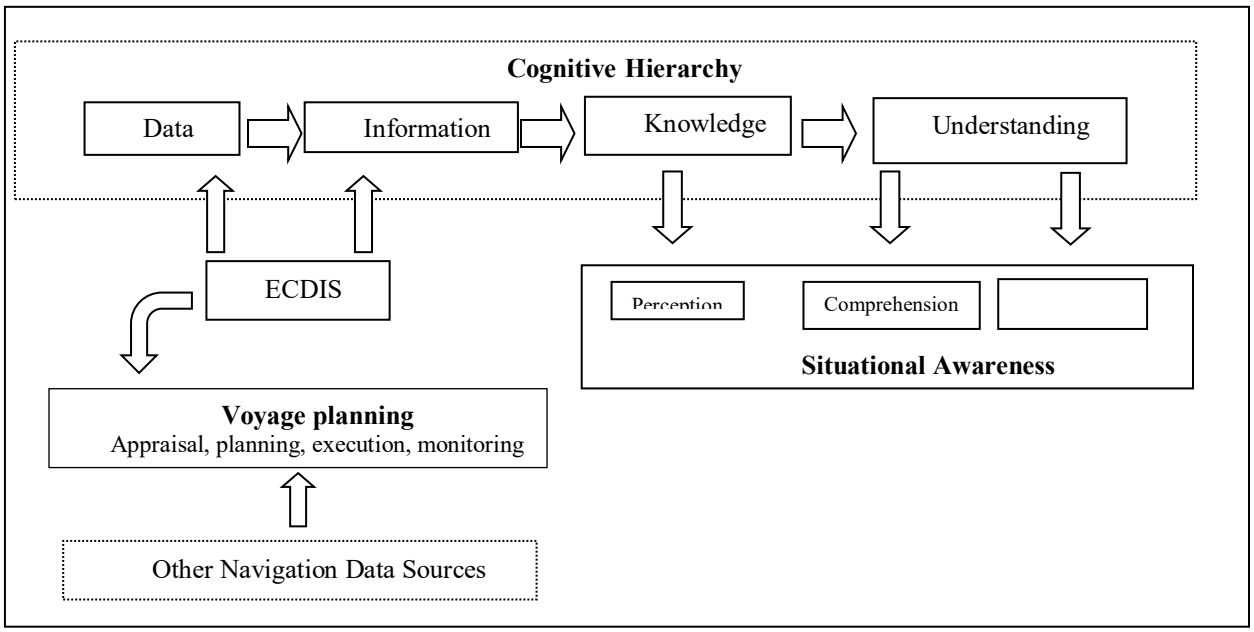

Figure 1: Cognitive hierarchy showing relationship between ECDIS and VP and SA
Source: Authors, developed from (6)

2 RESEARCH DESIGN AND METHODOLOGY

2.1 Objectives of the study

The objectives of the work upon which this paper is based is to determine the attitudes of ECDIS trainees towards the effectiveness of the system to increase situational awareness during voyage execution and monitoring and also in creating detailed and safe voyage plans. To gauge the soundness of the training a survey is given at the beginning of the training period and again at the end of the training period. A statistical comparison of the two surveys enables a subjective determination of whether the provided training is indeed having the desired effect, acceptance of the tenants of ECDIS best practices as being invaluable to increasing the OICNW's awareness of stationary and moving hazards to navigation that may threaten safe navigation.

2.2 Data collection and sampling

The research covers descriptive statistics, comparative analysis and correlation tests between the dimensions of SA and VP. Data processing is maintained by the SPSS 24 (Statistical Package for the Social Sciences) Program. Hypotheses tests (t-test) were conducted in order to find the significant differences before and after the training period. Correlation tests were conducted to find the relations between voyage planning and situational awareness dimensions.

To test the hypothesis of the research, a survey made up of three parts was developed. Statements concerning the objectives of the study were designed to ascertain the attitudes of trainees towards ECDIS and to explore the relationships between ECDIS, SA, and VP as perceived by the trainees.

The first part of the survey consists of three statements addressing the relationship between ECDIS and the three dimensions of SA (perception, comprehension, and projection). The second part contains three statements addressing the relationship between ECDIS with radar overlay and the three dimensions of SA. The third and final part of the survey is made up of four statements addressing the relationship between ECDIS and the four dimensions VP (appraisal, planning, execution, and monitoring).

A 5-point "Likert Scale" with anchors at 1 (very low) and 5 (very high) was used to assign a value to each survey statement response and enable a statistical analysis. There was one demographic question included to determine each trainees' major program of study.

The surveys were administered to Maine Maritime Academy cadets enrolled in E-Nav II, the Academy's course that focuses primarily on ECDIS training, during the Spring 2017, Fall 2017, and Spring 2018 semesters. Identical surveys were conducted at both the commencement and completion of each semester. For comparative analysis, forty-eight pre-course surveys and fifty-one post-course surveys, for a total of ninety-nine surveys, were collected from the same sample group. For descriptive statistics and correlation analysis, the post-course surveys only were used.

3 FINDINGS

3.1 Descriptive statistics

Overall mean scores and standard deviations are listed in Table 1. The statements on the surveys, column one of Table 1, completed by the trainees were preceded by "The impact of …", for example, statement one reads, in full, "The impact of ECDIS on improving perception." The possible responses are: 1-Very Low, 2-Low, 3-Adequate, 4-High, and 5-Very High.

3.1.1 Perception of students concerning relationship between ECDIS and situational awareness dimensions

In the first part of the questionnaire, the impact of ECDIS on increasing *Perception* (What is happening?) (μ= 4.4902) was found to have the highest mean score, 55% (n:28) of respondents indicating that the impact of ECDIS on increasing perception is very high. "The impact of ECDIS on *Projection*" (What will happen next?) (μ= 4.3725) has a higher mean score than "Impact of ECDIS on *Comprehension*" (What does it mean?) (μ= 4.3333). This result

indicates that ECDIS has more impact on improving *Perception* and *Projection* than *Comprehension*.

Accurate comprehension requires an adequate amount of pre-existing skill, knowledge and experience, traits that the navigator must possess and that ECDIS cannot provide on its own. ECDIS is better at answering the questions "What is happening?" and "What will happen next?". ECDIS by itself provides limited support in answering the question "What does it mean?", which relies upon the navigator's personal judgement to be answered accurately.

Table 1: Descriptive statistics

Statements	N	Minimum	Maximum	Mean	Std. Deviation
ECDIS Perception	51	3.00	5.00	4.4902	.61229
ECDIS Comprehension	51	3.00	5.00	4.3333	.62183
ECDIS Projection	51	3.00	5.00	4.3725	.59869
ECDIS with RADAR Perception	51	1.00	5.00	4.2745	.87358
ECDIS with RADAR Comprehension	51	2.00	5.00	4.0980	.85452
ECDIS and RADAR Projection	50	1.00	5.00	4.0200	.89191
ECDIS Appraisal	51	2.00	5.00	4.2745	.77662
ECDIS Planning	51	4.00	5.00	4.7059	.46018
ECDIS Execution	51	3.00	5.00	4.5294	.61165
ECDIS Monitoring	51	3.00	5.00	4.6275	.56430

3.1.2 Perception of students concerning relationship between ECDIS with radar overlay and situational awareness dimensions

According to IMO ECDIS Performance Standards (14), an ECDIS display may be used for the display of radar and/or radar tracked targets and it should be possible to remove the radar information by single operator action

Mean scores for statements related to SA and ECDIS with radar overlay are found to have less than mean scores with the statements ECDIS without radar overlay. This indicates that more information, like radar overlay, does not improve SA. Having more data on the screen has negative impact on SA.

Acquiring needed information and the method of presenting, or displaying, that information to the navigator has a great deal of influence on that navigator's SA. Both a lack of needed information and too much information can negatively impact SA. (15)

3.1.3 Perception of students concerning the relationship between ECDIS and voyage planning dimensions

In the third part of the questionnaire, the statement "The impact of ECDIS on planning" (μ=4.7059) is found to have the highest mean score, 70% (n: 36) of the respondents believe that the impact of ECDIS on voyage planning is very high. The other two statements having high scores are; "The impact of ECDIS on monitoring" (μ=4.6275) and "The impact of ECDIS on

execution" (μ=4.5294). "The impact of ECDIS on Appraisal" (μ=4.2745) received the lowest mean scores.

ECDIS provides limited support to navigators during the appraisal phase of voyage planning. Navigators require more information than ECDIS alone can supply in order to create a safe and efficient voyage plan such as: the condition and state of the vessel, its stability, and its equipment; any operational limitations; its permissible draught at sea, in fairways, and in pilotage areas; its maneuvering data, including any restrictions; characteristics of the cargo; existing radio navigational warnings; and other resources including but not limited to sailing directions, lists of lights and lists of radio aids to navigation, and mariners' routing guides.

3.2 Hypotheses test

In addition to the descriptive statistics, hypotheses tests (t-test) were conducted in order to find the significant differences before and after training, see Table 2, H_1, H_2, and H_3. Finally, the correlations between the voyage planning dimensions and SA dimensions were tested, H_4.

Four hypotheses were developed to test the study's objectives:

- H_1: Perception of students concerning relationship between ECDIS and Situational Awareness differs before and after training.
- H_2: Perception of students concerning relationship between ECDIS with radar overlay and Situational Awareness differs before and after training.
- H_3: Perception of students concerning relationship between ECDIS and Voyage Planning differs before and after training.
- H_4: Voyage planning dimensions are related with situational awareness dimensions

Table 2: Hypotheses test results

Hypotheses	Support	
	T	Sig. (2 tailed)
H_1: Relationship between ECDIS and Situational Awareness	**supported** t= -5.039, p>0,05	.000
H_2: relationship between ECDIS with radar overlay and Situational Awareness	**supported** t= -2.158 p>0,05	.033
H_3: relationship between ECDIS and Voyage Planning	**supported** t= -5.772 p>0,05	.000

The t-test results show the significant differences of the students' perceptions towards ECDIS before training compared to after completing training. These results demonstrate the positive impact of training on this group of students.

3.2.1 Testing hypothesis 4, Voyage planning dimensions are related with situational awareness dimensions

Correlations between voyage planning and SA dimensions were tested. The results for H_4 are given in Table 3, which presents the correlation coefficients of the variables in the study. The data indicates strong positive correlations between: ECDIS Perception and ECDIS Appraisal ($r=.637$, $p<0.01$); ECDIS Planning ($r=.451$, $p<0.01$); ECDIS Execution ($r=.468$, $p<0.01$), and ECDIS Monitoring ($r=.423$, $p<0.01$). Also there is a strong positive correlation between ECDIS Comprehension and ECDIS Appraisal ($r= .469$, $p<0.01$). The data indicates weak correlations between ECDIS Projection and ECDIS Monitoring ($r=.182$, $p<0.01$).

In summary, VP with ECDIS effects SA in a positive way. When we consider the VP dimensions (appraisal, planning, execution and monitoring), perception is correlated strongly with all dimensions of voyage planning. ECDIS derived information increases the navigator's perception, enabling more comprehensive VP. The graphical display of the VP on ECDIS simplifies the execution and monitoring of the VP. But VP only affects comprehension at a moderate level because comprehension requires basic knowledge and experience. VP by itself is not be enough to increase comprehension. Lastly we note that projection is weakly correlated with all four VP dimensions.

Table 3: Correlation matrix: Impact of ECDIS on VP and SA dimensions

	ECDIS Appraisal	ECDIS Planning	ECDIS Execution	ECDIS Monitoring
ECDIS Perception	0.637**	0.451**	0.468**	0.423**
ECDIS Comprehension	0.469**	0.280	0.316*	0.247
ECDIS Projection	0.335*	0.260	0.324*	0.182

** Significant correlation at the 0.01 level (2-tailed) Pearson Correlation
* Significant correlation at the 0.05 level (2-tailed) Pearson Correlation

4 CONCLUSIONS

The survey data collected from the students indicates that ECDIS increases the navigator's overall SA and improves VP. The results also indicate that the addition of a radar overlay on the ECDIS display decreases SA, possibly due to information overload and/or a lack of watch standing experience. The collection of survey data prior to and after training clearly shows an improvement in the students' appreciation of ECDIS capabilities. Lastly we note that SA and VP are strongly correlated and that VP improves perception, enabling an ECDIS navigator to more easily determine "What is happening?".

4.1 Limitations and further study

This study is based on data gathered at only one institution and the respondents' experience with fully implemented ECDIS was limited. For further study the attitudes of mariners having more experience with fully implemented ECDIS can be examined.

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