# Mersin University
# Journal of Maritime Faculty

*Mersin University Journal of Maritime Faculty (MEUJMAF)*
*Vol. 1, Issue 1, pp. 10-16, December 2019*
*Research Article*

## TRAINING SITUATIONAL AWARENESS AND DECISION MAKING FOR PREVENTING COLLISION AT SEA: A THEORETICAL BACKGROUND

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Received: 11/11/2019 Accepted: 19/12/2019

**ABSTRACT**
Maritime accidents are one of the main factors that disrupt maritime transportation. Among these accidents, collision situations, due to their frequency and consequences, possess a great threat to the safety of navigation. The majority of these accidents are directly related to the operations within the ship and human errors. In this study, we explore the importance and the training needs for situational awareness and decision making for preventing collisions at sea through a literature review. Studies suggest that seafarers on board who are responsible for keeping navigational watch can both be the causer and preventer for collisions. Recommendations of the studies in the field point to the need for specialized training to improve situational awareness and decision making. Training seafarers' expectations and goals for collision situations are proposed to achieve this improvement. Especially the usage of the training scenarios including unexpected situations to increase familiarity and readiness levels are referred frequently.

***Keywords:*** *Situational Awareness, Decision Making, Collision at Sea, Maritime Education and Training*

## 1. INTRODUCTION

Navigation safety is one of the top priorities of maritime transportation. Therefore, leading organizations such as the International Maritime Organization (IMO) are constantly focusing on activities that will enhance and protect the safety of navigation. Even though the decrease in maritime accidents, with the help of new technologies, stricter rules, and evolving policies, shows us that the overall change in maritime transport is towards a more positive and proactive position, accidents continue to occur. Accidents like collision, grounding, stranding, and breakdowns involving large ships result in major losses to human lives and create economic and environmental burdens (EMSA, 2018). Since casualties are mostly related with collision incidents that occur between vessels, for this study, we mainly focus on navigation safety through the collision situations.

It is important to understand the reasons behind the accidents, especially when accidents occur where something fails, and effective preventive measures can be taken (Hollnagel, 2002). The equation to maritime accidents and navigation safety consists many factors which one of them being the human factor (Rothblum, 2000). According to European Maritime and Safety Agency, human error represents 58% of accidental events occurred within the period of 2011-2017 (EMSA, 2018). Many studies also acknowledge the human element or human error as the main driving factor in accidents (Rothblum, 2000; Pourzanjani, 2001; Darbra & Casal, 2004; Toffoli, Lefevre, Bitner-Gregersen & Monbaliu, 2005; Antao ve Soares, 2006; Hetherington, Flin & Mearns, 2006; Eliopoulou & Papanikolaou, 2007; Ziarati & Ziarati, 2007; Martins & Maturana, 2010; Chauvin Lardjane, Morel & Clostermann, 2013; Batalden & Sydnes 2014; Uğurlu, Köse & Yıldırım 2015; Yıldırım, Başar & Uğurlu, 2017). Considering these statements, the consensus in the literature is to implement various procedures to reduce human error to improve maritime safety.

Focusing on seafarers on board of ships to achieve the desired safety levels seems to be a valid method since 70% of accidental events have shipboard operations as the contributing factor (EMSA, 2018). For collision accidents the human element on board ships describes a specific workgroup known as deck officers or officers of the watch. A deck officer is a seafarer usually assigned with the duty of watchkeeping on a ship's bridge. The officer of the watch has the responsibility of safe navigation and needs to ensure that the ship complies with International Regulations for Preventing Collisions at Sea (COLREGS). They are considered the first and the last measure in preventing collisions at sea. That’s why the competency of this personnel remarkably important in collision situations. As Nikitakos et al. (2017) state, there is a direct relationship between the effective, safe and environmentally sensitive functioning of maritime transport and qualified seafarers. It is evident that the continuous development of seafarer capabilities and competencies are required. Therefore, to stride towards a safer maritime system the current performance failure of the human element should be identified, and then these shortcomings should be supported by appropriate learning theories and designs.

## 2. THE HUMAN ELEMENT IN MARITIME

The concept of the human element or human factor is widely used in psychology, organizational behavior, ergonomics, human-computer interaction, safety science, human resource management, health sciences, sociology, anthropology, and many other fields. The energy and aviation industry as well as the military, where the safety and security are at the forefront, pioneered the studies on the human element. Similar to these fields, maritime transport is very sensitive to human errors and depends greatly on human performance. However, the concept of the human factor/element is a broad subject that contains many topics within itself. IMO (International Maritime Organization) defines the human element as the entire spectrum of human activities performed by ships' crews, shore-based management, regulatory bodies and others (IMO, 2019). Therefore, it is obvious that the “error” in the term “human element” should be defined more clearly.

The Human Factor Analysis and Classification System (HFACS), developed by Shappell and Wiegmann (2001), based on Reason's (1997) model, defines human factor at four levels. These; are “unsafe acts”, “precondition for unsafe acts”, “unsafe supervision” and “organizational influences” (Shappell and Wiegmann 2001). The Human Factor Analysis and Classification System can easily be adapted for defining human errors in maritime transportation. There are already many examples of scientific research conducted within this framework to analyze maritime accidents. Most of these studies indicate the main causes of accidents as unsafe acts and preconditions triggering those acts. In addition to that, perceptual errors, decision errors and skill-based errors under the unsafe acts found to be the prominent elements in accidents (Pourzanjani, 2001; Çelik & Çebi, 2009; Chauvin et al., 2013; Batalden & Sydnes 2014; Yıldırım et al. 2017). This finding basically translates to a deficiency in the non-technical skills of individuals, namely situational awareness and decision making. Many other studies not utilizing HFACS also suggest similar findings as such; the situational awareness being one of the most dominant factors in the formation of human error in maritime (Baker and McCafferty, 2005; Barnett, Gatfield & Pekcan, 2006; Ziarati and Ziarati, 2007; Smith and Jamieson, 2012; Sandhåland, Oltedal & Eid, 2015; Øvergård, Sorensen, Nazir & Martinsen, 2015; Cordon, Mestre& Walliser, 2017; Barnett & Pekcan, 2017). Recalling the case of shipboard operations being the contributing factor, we argue that implementing processes to improve situation awareness of officers of the watch can reduce perceptual and decision errors which in return will improve the safety of navigation.

### 2.1. Situational Awareness

Situation awareness is defined as the perception, comprehension, and projection of the elements in the environment within a specific time and space (Endsley, 1995). Perceiving the elements, comprehending their meaning, and projecting their future status is considered as a three stepped hierarchical structure in Endsley's (1995) SA model. According to this model, situation awareness is linked with system factors (complexity, automation, workload, etc.) and individual factors (expectations, abilities, training, experience, etc.).

For an officer of the watch on ship's bridge keeping a navigational watch this can be structured as (Chauvin, Clostermann & Hoc, 2008);

- Level 1 SA: location, heading, and speed of own ship and other vessels, distance at the closest point of approach with the targets.
- Level 2 SA: meaning the elements perceived in level 1, meaning the situation: a safe crossing or a dangerous crossing situation, head-on situation.
- Level 3 SA: Possible future actions of the target ship, projection of the situation in the near future: crossing from the bow, possible collision or safe passage.

A possible error in Level 1 SA would be the entirely missing an information (failing to notice an echo on the radar) or misreading information. Since attention and working memory capacities are limited these faults could be considered typical errors in situation awareness. An error in this level affects both SA level 2 and SA level 3. At SA level 2 conditions like stress, information overload or limited experience can prevent an officer to comprehend situation straight. Error on this level greatly hinders an individual's ability to predict upcoming events (Sandhåland et al., 2015).

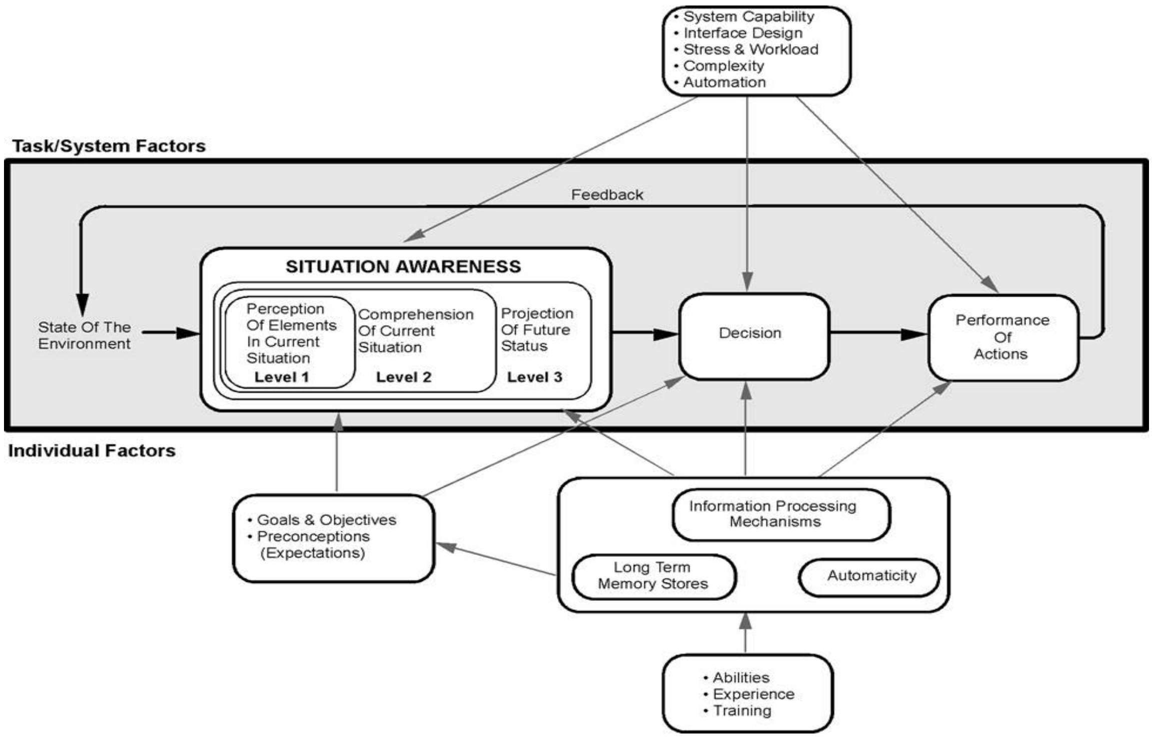


Fig. 1. Situation Awareness Model, Source: Endsley, 1995

The term situation awareness by the terminology describes the state of knowledge, but not the process used to achieve that state. An individual's process to achieve that state (acquiring or maintaining SA) is defined as situation assessment (Endsley, 2017). In both of these, patterns stored in individuals' memory are used to create a mental model. Mental models direct how one solves a problem and makes a decision. It is stated that decision making is heavily influenced by the situation awareness in a way that situation awareness is a prerequisite for quick and good decisions (Endsley, 2017; Lipshitz, Klein, Orasanu & Salas, 2001). Ultimately, decision making combined with the technical skills of the operator creates the performance. Considering the collision and emergency situations it is particularly important that the deck officer has the ability to assess the situation continuously to reach a quick and good decision to avoid any accident (Sandhåland, 2015).

## 2.2. Decision Making

We see various approaches have been adopted in decision-making researches in order to understand the decision-making processes of the operators. Between those two of the decision theories stand out in the literature. Rational decision-making approach states that the traditional problem solving is usually done from one stage to another using a set of rules such as defining the problem, generating an action, evaluating the action, and implementing the action. In rational decision-making, it is suggested that the decision-maker makes a comparison of a set of known and defined options, evaluating the possible outcomes for each option and selecting the appropriate one (Kobus, Proctor & Holste, 2001). However, it has been found that this approach does not fully explain decisions made under stress, time pressure and with limited resources (Bohanec et al., 2009; Klein, 1997). This is because in dynamic situations the problems are more ill-defined rather than being structured and having well-defined goals (Klein, 2008).

Naturalistic decision-making studies have arisen due to an increase of indications that people do not make the ideal decision contrary to expectations in difficult conditions (Gore, Banks, Millward & Kyriakidou, 2006; Klein, 2008). Naturalistic decision-making is an approach that aims to explain how decision-makers make decisions under difficult circumstances in real life (Klein, 2008). Klein's recognition-primed decision (RPD) model states that people do not carry out a formal comparison between options and the experts in the area can generate a single and satisfying action by using their experience (Klein, 1997; Klein, 2008). According to the RPD model, experts can make quick and proper decisions by using environmental cues and matching the patterns (Klein, 1997; Klein, 2008). In the RPD model, the recognition of the situation through situation assessment is the priority when carrying out the decision (Brytant, Webb & McCann, 2003; Klein, 2008). Alternatives to the solution are not compared one-to-one to choose the best action. For example; in a man overboard situation a captain instead of analyzing the best course of action methodologically, will aim to select the fastest and most plausible action from his "mental database" through a situation assessment that will enable him to take man overboard back to the ship.

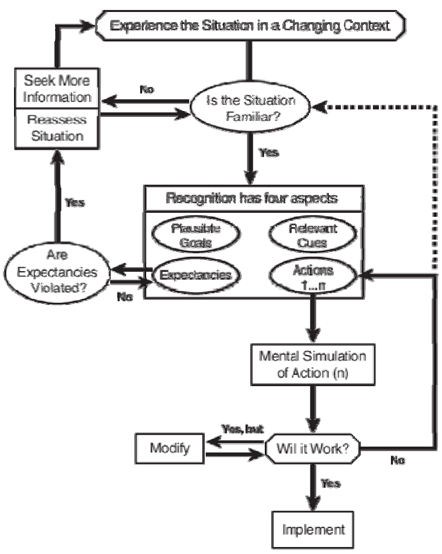


Fig. 2. Recognition Primed Decision Model
Source: Klein et al., 1993

RPD model defines four elements as the keystone to recognition. These are perceptual cues, goals, expectations, and actions (Klein, 2008). These elements are also the key factors in situational awareness according to Endsley's (2017) model. Since situation awareness is a prerequisite for quick and good decisions, the assumption is: situation assessment conducted by the operator enables him to build and maintain situational awareness and therefore recognition of the situation can be assessed, and the right decision can be made. Therefore, lack of situational awareness is what essentially creates the faulty decision making resulting in poor performances. However, in this context, SA errors should not be confused with decision errors. Poor situation awareness might create such an environment that officers can think that they made the right decision based on their perceptions (Sandhåland, 2015). Likewise, lack of situational awareness cannot account for all performance shortcomings of the operator. Yet it is essential to evaluate situational awareness together with the decision making.

## 3. TRAINING SITUATION AWARENESS AND DECISION MAKING FOR EMERGENCY COLLISION SITUATIONS

Interactions between vessels in maritime traffic is a dynamic process, in which complexity can steadily or instantaneously change (Brčko, 2014). In this kind of operational setting, watchkeepers might not have enough time to generate a series of actions, make an analytical assessment and choose the best decision (Kobus et al., 2001). The act of collision avoidance at sea is basically a test of situational awareness (perceiving incoming ships, comprehending the situation and predicting the outcome), decision making (turn to port/starboard, stay on course) and technical skills (adjust course). A deck officer on navigational watch must act decisively during stressful and high-risk situations. Considering these, the RPD model interlinked with the situational awareness model can be used to explain operational decisions taken by the officers of the watch in collision avoidance settings. This is also supported with the fact that several studies on the deck officer's decision making and situational awareness on the ship's bridge focus on natural decision making, recognition primed decision and Endsley's situational awareness models (Chauvin & Lardiane, 2008; Chauvin et al., 2009; Chauvin, 2011; Harvey, Zheng & Stanton, 2013; Øvergård et al., 2015; Sitka, 2016; Imbsweiler et al, 2018).

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (the STCW Convention), went through revisions in June 2010. Revised STCW Convention and Code adopted at the Manila Conference are called "The Manila Amendments" (IMO, 2019). The Manila amendments make emphasis on the needs for training of non-technical skills for good seamanship with the introduction of modern training methodology including distance learning and web-based learning. Situational awareness, decision making, leadership, and teamwork are mentioned as the non-technical skills in the amendments. The STCW Convention states that the way for future seafarers to be able to handle critical situations, their training must be tailored to enable them to "effectively obtain and maintain situational awareness and apply decision-making techniques in order to conduct situation assessment, generate, identify and consider options, select a course of action and evaluate the outcome" (IMO, 2010: STCW Code Table A-II/1) This standard set alone should suffice for creating specialized trainings for non-technical skills. With this in mind, considering the previously mentioned theories for creating training on situational awareness and decision making seems to be the way to reduce most of the collision accidents.

A large part of maritime education is done with formal education and seminar-style instruction in the classroom. Through the education given in the classrooms, individuals learn the theories, concepts, and rules of the related subjects and gain knowledge about the functioning of the systems. However, the design of this training generally does not provide an environment for individuals to develop the abilities or skills for certain subjects. That is why education given in the classrooms is supported by high reality applications like simulators. Individuals with theoretical knowledge about the subject then have the opportunity to develop and improve their skills through realistic exercises. In addition to these, most of the maritime students undergo through an open sea training which supports both theoretical and practical skills of individuals with experience. However, there are certain disadvantages arising from the methods used within the framework of this training model. The duration of the individual training given in the simulator is limited due to the time required for each practice as well as the number of trainers and students. Therefore, it is a common practice to form bridge teams for simulator trainings which further limit the development of individual decision-making capabilities. This also limits students' ability to become familiar with the unusual events and emergency situations. Training onboard ships suffer from a different problem. There is a possibility that individuals, unlike in the simulator training, may not face with conditions that include negativities or unexpected situations. This is expected since we want the safe operation of the ships at all times. In the end this condition prepares students for the routine operation of the ship rather than for emergencies or unusual conditions. Several studies put forward a theoretical framework and various recommendations for this subject.

According to Chauvin & Lardjane (2008), it is possible to increase the familiarity and readiness levels of seafarers for emergency situations by improving their mental models and pattern recognition abilities. Sandhåland et al. (2015) support this claim with a similar finding. They revealed that insufficient training was the most common contributing cause in their research for failure to comprehend the situations which result from poor mental models. These mental models can be improved by the use of scenarios involving unusual and complex maritime traffic situations in training. This will enable more effective implementation of the COLREGs and reduce human errors in collision situations (Demirel & Bayer, 2015a). Various scientific studies also support these views; emphasizing the specialized training for decision-making to support deck officers' collision prevention performances. According to Pekcan et al. (2005); decision-making exercises will improve deck officers' ability to analyze complex situations (Pekcan, Gatfield & Barnett, 2005). Good decision-making is not only influenced by experience, age, and education, but also by specialized training. Recognizing complex patterns (pattern matching) would enable watchkeepers to find appropriate options to solve various problems more easily (Chauvin et al., 2009). This means training the expectations and anticipations of the students will provide a learning to observe the traffic situation, even if one is not directly involved in. According to Brčko et al. (2014), these statements mainly emphasize the importance of training of deck officers' expectations and goals. Accordingly, the deck officers' observations of maritime traffic and their ability to react quickly with the situation assessment in a distress are proportional to the expectations and familiarization of these individuals. Sitka (2016) in their study examining the decision-making of deck officers concludes that the use of cognitive teaching tools as early as possible in the education process would support the development of decision-making skills of maritime students. Chauvin et al. (2008) states that new educational tools such as decision-making practices/exercises are worth using in maritime education. In their study, these researchers described decision-making exercises as low-reality processed simulations of situations that might actually occur (in the field). Chauvin et al. (2008) recommends; presenting a dilemma to students to decide and giving them a few minutes to determine their actions. In this way, it the participants will gain experience on important clues, incorrect evaluations and the types of uncertainties encountered. Demirel and Bayer (2015b) suggest that a training based on possible and unusual scenarios would help to understand COLREG better with the help of an information-based tool such as e-courses. Chauvin & Lardjane (2008) similarly emphasized the importance of identification of relevant patterns and clues to prevent collision at sea and the mental models they will use to achieve satisfactory decisions. Chauvin et al. (2009), stated that in French maritime schools, the simulators were used to provide trainees with experience for difficult situations. However, they stated that the emergency scenarios processed in the simulator could not be repeated to ensure that the students were able to respond accurately and quickly. They emphasized that pattern matching, and correct action selection are gained by repetitions of these practices. At this point, the researchers recommended that decision-making exercises should be used to introduce maritime students to specific difficult situations.

## 4. CONCLUSION

In general, the primary role of deck officers is to maintain the safe course of ships on a pre-designated route. In this context, the officer of the watch (OOW) is usually the ultimate decision-maker in avoiding collision situations during the navigational watch. In order to avoid collisions quickly and accurately officer of the watch must not only possess near-perfect knowledge of International Regulations for Preventing Collisions at Sea (COLREGs) but also requires adequate skills to implements COLREG rules. This means a deck officer may fail to avoid collision due to insufficient navigational knowledge, observation capability or lack of situational awareness, even though he is fully aware of the rules defined in the COLREG. Additionally, complex traffic conditions where it is difficult to interpret the rules can cause perception and decision errors. Also, in tight emergency situations, an action that first seemed to be reasonable may lead to then unforeseen distresses. When these conditions are evaluated, it is crucial to set the expectations and goals of the situation accurately and quickly in order to prevent situations from going beyond recovery. The way to achieve these lies within the specialized situational awareness trainings and decision-making practices. In addition to informing students with theoretical aspects of situational awareness and decision making, we should aim for shaping their mental models and improving their pattern and situation recognition capabilities. This can be achieved with practices and exercises, using either already available simulators or creating new tools to help them set their goals, expectations and possible actions right in collision situations.

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