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Human factors in seafaring: The role of situation awareness

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ABSTRACT

The main goal was to identify Human Factors in seafaring. First, a group of experts made a list of adjectives. Then, a sample of 141 Officers were asked to give their opinion about the importance of each adjective in Seafarer's behaviour. Exploratory Factor Analysis and Confirmatory Factor Analysis through Structural Equation Modelling techniques were applied to the data. Two factors were identified in aptitudes: "Situation awareness" comprising adjectives from levels 1-2-3 SA; and "adaptability". From attitudes, first component is "Self-Knowledge", component 2 "Group Skills" and component 3 "Drive". Structural Equation Modelling confirmed the factor structure previously found. It can be concluded that: SA would be a key factor in Sea Navigation, there is psychometric evidence of the construct validity; and Human Factors in seafaring can be described using a five-factor model.

1. Introduction

1.1. Human factors in maritime navigation

In 2010, the International Maritime Organization (IMO) pointed out clearly that:

> the key to maintaining a safe shipping environment and keeping our oceans clean lies in all seafarers across the world observing high standards of competence and professionalism in the duties they perform on-board. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended in 1995 and again in 2010, sets those standards, governs the award of certificates and controls watchkeeping arrangements. Its provisions not only apply to seafarers, but also to ship-owners, training establishments and national maritime administrations.
>
> [IMO, 2010, p. 1]

The latest revisions of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) include for the first time non-technical training aspects such as personal, group and leadership skills. These amendments, known as Manila Amendments (IMO, 2010), are related to: (a) Bridge Resource Management; (b) Engine-room Resource Management (c) Leadership and Managerial Skills, and (d) Application of Leadership and Team-working Skills, require the IMO States Members to implement seafarers training policies not only focused on the technical aspects, but also on the performance in the Navigation Bridge Management and in other duties performed on board.

Previously to the adoption of the so called Manila Amendments, several studies on human factor applied to maritime fields were published. In 1997 Koester (1997) updated several concepts on human factor and its application to seafaring. In subsequent studies, Hetherington et al. (2006), highlighted the importance of the human factor in the field of navigation in relation with maritime safety.

1.2. Situation awareness and sea navigation

Although during the last 20 years SA construct has been mainly applied to the field of aviation rather than to maritime navigation, nevertheless, several studies were carried out in this field.

Grech et al. (2002) analysed a number of accident reports and its relation with the lack of Situation Awareness (SA) in order to determine whether or not SA was a relevant issue in merchant shipping operations. Other authors have studied in depth a number of factors affecting the performance of mariners, noting that SA is a major issue, but considering each component as workload or attention individually (Grech et al., 2008; Koester, 2003, 2007). In addition, Chauvin et al. (2013) demonstrated the applicability of the

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construct to risk in manoeuvres during maritime navigation. This study presented a decision making model for ships crossing situations using the Endsley SA three levels approach (1995).

Lately, SA has also been applied to maritime traffic control. In this field several studies have been published. It worth to highlight the studies carried out by Nilsson et al. (2008) who identified factors used by expert VTS operators to get and keep SA in maritime surveillance. Wiersma (2010) who performed a practical use of SA for VTS in the Port of Rotterdam, Van Westrenen and Praetorius (2012) who developed a theoretical approach to maritime traffic control (VTS) using SA construct in and They showed the utility of using SA to asses performance in VTS; similarly, Wiersma (2010) performed a practical use of SA for VTS in the Port of Rotterdam and Cordón et al. (2014) assessed the SA in VTS operators, and performed and validated a psychometric approach of SA.

1.3. Endsley's situation awareness model

SA Endsley's model (1995) describes a three-level decision-making process, starting from perception of the situation (Level 1), comprehension (Level 2) and finally its projection (Level 3). SA construct has been widely adopted by researchers in several areas, such as air traffic control and navigation, power plants, surgery and so forth.

Despite the existence of abundant literature regarding the use of SA in different fields, there is no empirical or psychometric basis to state that it is useful and appropriate in a particular context; hence there is much debate. Recently, Endsley (2015a, 2015b) has pointed out several theoretical issues still remain under discussion. For example, Salmon and Stanton (2012, p. 1) discussed about SA and security, claiming that:

> SA has always been a highly contentious concept, with much debate over theories (e.g. Salmon et al., 2008; Stanton, 2010), measures (e.g. Stanton et al., 2006) and even questions over its existence as a valid ergonomics concept.
>
> [Dekker and Hollnagel, 2004; Dekker et al., 2010]

In addition, several authors complained about the lack of theoretical and methodological consensus. Others have pointed out the ubiquity and the illegitimacy of SA (van Winsen et al., 2014). Furthermore, other SA models have appeared: Sensemaking (Klein, 2014), Distributed SA (Stanton et al., 2014) and Situated SA (Chiappe et al., 2015). Those models or paradigms have been discussed by Endsley (2015a, 2015b), who stated:

> "On the contrary, pilots invented SA—it was a part of their vocabulary and conceptualization of their world long before any of us got involved in trying to describe it, measure it, or design for it. They would be talking about it (and lamenting not having it), whether we were doing anything to help them with it or not (see Byrne, 2014)."
>
> [Endsley, 2015a, p. 4]

We agree with this idea and believe that her model is relevant and useful in seafaring. SA is part of people's thinking who deal with complex tasks in the bridge of a vessel, similarly to any aircraft. In fact, although this study is based on Endsley's model, our research provides a new basis to develop or refine those models.

Our working hypothesis is that SA is a factor underlying seafaring and can be applied to the most important Officer's roles, as shown using the Goal-Directed-Task-Analysis (GDTA) (Endsley and Jones, 2012). Table 1 summarizes the main roles for the three levels in Endsley's SA construct/model.

Therefore, we need to define exactly what the characteristics to be assessed are in officers' behaviour and how they should be measured to enforce legislation. Then, the primary goal of this work is to confirm the role of SA on-board and put in some evidence on construct validity in the seafaring context. The second goal is to develop a psychometric model of aptitudes and attitudes that describes seafarers' behaviour (regarding Human Factors in Maritime Navigation). Further relevant relationships between factors will be studied in the following sections.

2. Method

2.1. Participants

A convenience sample of Marine Officers were chosen for this research (N = 141, 109 were males and 32 females). These individuals were required to fill out two questionnaires. Both questionnaires were available online, in Spanish and English so they could be easily filled out by as many people as possible. Finally, most of them, 80%, were filled out in Spanish. Convenience sample was used to find the most heterogeneous population as possible in terms of age and type of experience. Sample size was limited for the difficulties to reach the seafarer's population which most of them were sailing across the world; the sample comprises Officers coming from a wide variety of vessels (from large tankers and bulk-carriers to tugs, research, passenger, ferries, etc. Three participants came from the navy, 13 from the Coast Guard and 115 from Merchant vessels (see Table 2).

2.2. Procedure

First, a group of experts (N = 18; 17 male and 1 female, age $M = 54$; $SD = 7.6$) were asked to elaborate two lists of adjectives what they think the desired or best characteristics of an Officer's

Table 1
Examples of perception, comprehension, and projection elements for sea navigation and work management on board.

Domain	Perception	Comprehension	Projection
Sea Navigation	Harbour location	Sea/traffic conditions. Port regulations. Geographical and tidal conditions	Projected course of own vessel and others. Reporting duties
	Traffic on Course	Traffic advises. Traffic in the area. IMO regulations to prevent collisions. Own and others' vessels characteristics	Projected course to ensure security. Predicted dangerous manoeuvers. Radio contact with other vessels/VTS
	Possibility of failure	Availability of external help (e.g. tugs, anchorage areas)	Find alternatives to deal with the failure
	Load status or passengers	Possibility of cargo damage/personal injuries	Efficient navigation, management of meteorological circumstances and characteristics of the vessel
Work Management on Board	Resources available	Type of staff, capacities and abilities related to work	Work assignment both in harbour/sailing
	Motivation	Personal characteristics of the crew, family, salary, ethnic, etc.	Motivational Leadership
	Bureaucracy	Effective time management	Being able to manage properly self and subordinates' time delegating menial jobs