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RESEARCH PAPER

Ship sense—striving for harmony in ship manoeuvring

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Abstract Ship manoeuvring is something that many seafarers perform, although little attention has been devoted to this in research literature. The topic has generally been explained by members of the trade as gaining knowledge through experience. The purpose of this study was to identify which factors contribute to the perceived state of a ship's physical condition during manoeuvring. Eight master mariners were interviewed. The data resulted in a division of a sea voyage into three different phases, each requiring varying levels of effort from the bridge crew. The results further describe how the shiphandler strives for harmony between his ship and the environment. This is accomplished by personal factors such as spatial awareness, knowledge and experience to handle environmental factors of context, situation and vessel specific factors of inertia and the use of navigational instruments.

Keywords Navigation · Ship handling · Human factors · MET

1 Introduction

A regular sea voyage can be divided into different phases. The journey starts by departing the harbour and further, under way, you sail through the archipelago in regulated fairways before you reach the open sea. In some waters there may also be regulated shipping lanes. Navigation route and course is decided by the bridge crew depending on type of ship and cargo.

These phases require differing levels of control depending of the complexity of the situation. A parallel comparison can be made between a shiphandler and a car driver. Driving task difficulty is presented by Fuller (2005) in the task-capability interface (TCI) model, representing the driving task demands in the automotive domain (environmental factors, other road users, operational features, elements under direct

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operator control) and how they are balanced by the drivers capability (biological capabilities of the driver, knowledge and skills) to achieve control over the situation. In the shipping domain Chauvin, Clostermann and Hoc (2009) further emphasize the role of control as essential for seamen in their study on facilitating the apprenticeship of decision making in junior deck officers.

Depending on the type, size and area of operation, the bridge crew of a ship can have different formations of crew members which is governed by the regulations of local authority (Transportstyrelsen 2010b). The common formation is that of a commander, i.e. the captain of the ship, nautical officers such as a first and a second mate and possible deck ratings acting as helmsman or lookout. The helmsman does not formally have any navigational responsibility, he executes orders from one of the other members of the bridge crew higher in command. Although the manoeuvring of a ship can be seen as a team activity, the present study focuses on the single individual in charge of manoeuvring the ship, in this paper referred to as the shiphandler.

International and national legislation govern that all seafarers have common theoretical knowledge and, although limited, practical experience at the beginning of their career. This is regulated through the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (IMO 2011), and the national legislation (Transportstyrelsen 2010a).

Previous comparisons made between ship handling and automotive driving mostly concerns traffic separation, decision making and collision avoidance (Chauvin and Lardjane 2008; Westrenen 1999). However, the uniqueness of the shipping domain lies in the contextual factors in which the manoeuvring takes place. Water has very different characteristics compared to that of the road on which cars are driven. The friction between the water and the ship is also much less compared to that between the road and the tyres of the car. External forces act on the vessel such as wind against the ship's hull, resulting in considerable "slippage" in directions other than that of the intended course. Further, the sheer mass of the ship combined with the much smaller engine power provides a much less power-to-weight ratio compared to automotive driving, to be used to countermeasure the external effects to be able to keep to the intended track (Martin et al. 1998).

To accommodate for this, the shiphandler needs to constantly think ahead in order to anticipate future actions. This involves understanding the environmental conditions, timing of engine and rudder commands and sensing the relative motion to predict own and surrounding ships future position. Manoeuvring is as such seen as a context-specific action (Martin et al. 1998).

Baillie (1997) described that competent shiphandlers need to gain and possess both skill and knowledge during officer training. According to Crenshaw (1975) and Martin et al. (1998), ship manoeuvring requires both theoretical knowledge including the physics of acting forces and knowledge of the manoeuvring capabilities of the ship. But ultimately, this knowledge must be put into practice (House 2007; Hunt 1997; Roberts 1997; Lützhöft and Nyce 2006), thus emphasizing the importance of practical training for maritime officers. This makes the art of manoeuvring ships comparable to a craft-like profession.

The art of ship manoeuvring is commonly incorporated in the traditional term of Shiphandling and Seaman's eye (Crenshaw 1975). It is described that to excel in shiphandling one must have the skill to get the ship unharmed through severe weather and sea conditions and be proficient in handling the ship in and around harbours. Seaman's eye is harder to explain as different persons put different meaning to the expression. Crenshaw (1975) explains it from his experience as being an expression of competence at sea. To be able to filter and make use of all the information available and combine this with knowledge of the ship's characteristics and by judgement in order to take proper course of action. On the other hand, Brogdon (2001) and early research in the US Navy (1945) only suggest visual navigation, i.e. the use of the relationship between the size of visible objects and the angles between them to the term seaman's eye, thereby making it more of a constituent incorporated in the wider meaning of shiphandling. Whatever interpretation regarding the meaning of seaman's eye used, shiphandling and seaman's eye are as far as this present study concern, the only evidence of related topics. However, no further scientific evidence explaining the foundations of what the constituents are behind these, other than personal experiences and tales from the trades, exist.

The automotive domain has a long history and large body of research on driver behaviour. Starting as early as the 1930s research from the perspective, driver's task and use of perceptual information, see for example Gibson and Crooks (1938). Later, research led to theoretical models on driver behaviour, see for example Hollnagel et al. (2003) and Fuller (2000). Different aspects of ship manoeuvring exist within the literature, mainly in the form of handbooks such as The Nautical Institute on Pilotage and Shiphandling (The Nautical Institute 1990) and The Shiphandler's Guide (Rowe 2000). When talking to mariners with shiphandling experience regarding the manoeuvring of ships from a shiphandlers perspective, they are all familiar with what we ask them to describe but they find it difficult to explain. Although, as stated above, similar research exists in related domains, it does not mean that it is transferrable to the shipping domain (Wilson and Norris 2006).

Previously, a pilot study was performed examining the factors used by shiphandlers when manoeuvring ships (Prison et al. 2009). This study identified experience and training as important factors to succeed in manoeuvring as well as perceptual, visual, abilities but also proprioceptive cues.

This present study will explore the skills of ship manoeuvring and the underlying cues used by the shiphandlers. These skills have not been previously explained in this context and are not covered in the definitions of either ship manoeuvring or seaman's eye. Further, these skills are presumed to exist and play an important role in the dynamic interaction between a ship and the shiphandler. Since nor traditional ship manoeuvring or seaman's eye cover these skills, we have labelled it as ship sense. Drawing on conclusions from previously described studies, ship sense seems to consist of both cognitive and perceptual capabilities. This includes knowing what information to look for, where to find it and how to use it to be able to manoeuvre the ship and determine how successful a mariner is in his/her profession. This, together with our belief that this knowledge might be of tacit art (Polanyi 1966), further contributes to the assumption that this knowledge is not something that primarily can be observed, but rather has to be explained in context.

Eight certified master mariners were interviewed using standardized, open-ended questions. Grounded Theory was used for the analysis of the interview data (Corbin and Strauss 2008) and the method was chosen based on several facts. Primarily, by being inductive, it fits the exploratory approach taken in this study. Further, it allows for the researcher to account for previous knowledge thereby allowing the researcher to use that knowledge when interpreting the data and still obtain valid and reliable data (Corbin and Strauss 2008). The method also puts effort on connecting categories derived from the data and to connect these into relations.

The purpose of this study was to identify which factors that constitutes the shiphandler's perceived state of a ship's physical condition during manoeuvring.

The increase in knowledge regarding ship manoeuvring will hopefully contribute to the area of operational perspective for which there is a lack of scientific studies. Further, it can serve the maritime domain in several areas: development of training programs for manoeuvring, both for students and professionals and contribute to suggestions on the organisational level regarding the incorporation of junior officers in manoeuvring duties otherwise run by senior officers.

2 Method

Standardized, open-ended interviews (Patton 2002) with master mariners were used for data collection. Grounded Theory was used for the analysis of the interviews including coding, constant comparison and integration (Corbin and Strauss 2008).

2.1 Participants

Eight participants were interviewed regarding the manoeuvring of ships. The inclusion criteria for participants to take part in this study was that they were required to be certified as a master mariner and presently active in their profession at sea. The sample of participants was purposefully selected through a stratified chain sampling (Patton 2002) and for being experienced with manoeuvring in restricted waters and in harbours. The participants were contacted either by e-mail or by phone. Their active time at sea varied between 2 to 15 years, average: 10 years, and all participants where Swedish males. Their age ranging from 34 to 53 years old, average: 42 years old. Out of the eight participants, six were currently working as pilots. The concept of theoretical saturation was used to decide on the sample size. Theoretical saturation is achieved when the collected data no longer provides additional categories or adds to a deeper understanding of existing categories (Corbin and Strauss 2008).

2.2 Procedure

The interviews took place at Chalmers University of Technology, Gothenburg, Sweden. All participants were, prior to the interview, informed of the purpose of the study, which conformed to the declaration of Helsinki. It was further explained that the participants were there in the role of being master mariners and were not representing anyone else or organisation except themselves. All participants signed a written consent.

The interviews were standardized open-ended in an individual, face-to-face format (Patton 2002; Robson 2007). All participants were asked the same questions in the same order. Although using the standardized format, the use of follow-up questions in order to explore certain areas in greater depth when appropriate together with comments and elaborations from the participants, were allowed for all questions. A voice-recorder was used to document the interviews together with written notes.

2.3 Analysis

Grounded Theory was used during the process of analysis (Corbin and Strauss 2008). MAXQDA (Kuckartz 2007), a text analysis tool software was used for the analysis. Transcripts of raw data were coded within the software into concepts through constant comparisons. Diagrams were used to visualize the coded data as aids in the process of comparison and categorisation, resulting in the generation of a core category with its sub-categories and respective factors.

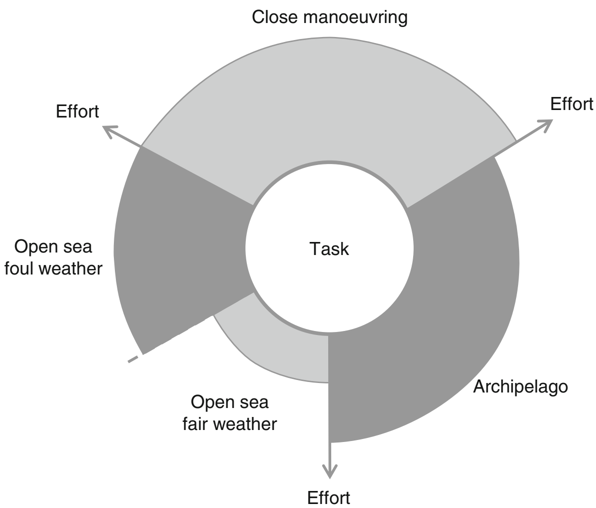
3 Result

The purpose of this study was to identify which factors that constitutes the perceived state of a ship's physical condition during manoeuvring. The interview manuscript divided the standard sea voyage into three phases. Further, the analysis of the interview data confirmed this division resulting in three different contexts. The result of the data analysis also added the respective level of effort required from the shiphandler to completing the task, implying successfully handling the ship in the different contexts.

The three contexts are the close manoeuvring phase, i.e. manoeuvring in very constricted areas such as harbours. The archipelago phase, i.e. on the way in or out to/from the harbour before you reach the open sea. In the archipelago, there are often manoeuvring constrictions such as fairways, islands and other more dense traffic. Lastly, the open sea where there is less traffic and fewer, or no geographic constraints.

Figure 1 shows a schematic representation over the different contexts with their respective demanded efforts indicated on the three axes. The levels of effort are

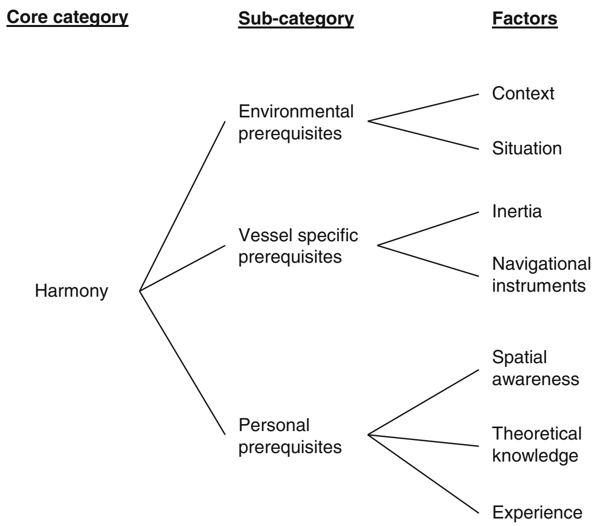
Fig. 1 Schematic representation of the different contexts and their estimated levels of required effort



estimations from the data collected from the participants in the study and are not measured values. We present them here to exemplify the different levels of effort for the different contexts. As can be seen, the context requiring the most effort is the close manoeuvring phase, which requires a high level of activity from the shiphandler. The phase while sailing through the archipelago phase requires less effort. Here, it is more the question of keeping the predetermined course and watch out for other traffic. It is more of a strategic problem about planning ahead than that of close manoeuvring although in every turn it requires a higher degree of effort to accomplish a well performed manoeuvre. The lowest level of effort was found at the open sea context. The task is more about monitoring the ships position and track as there are fewer manoeuvres to be made. Although in foul weather, the task moves from monitoring to more active manoeuvring as the ship has to be steered manually when the autopilot fails. This results in a higher effort for the bridge crew comparable to that of the close manoeuvring phase.

The shiphandlers strives for harmony between the ship and its surrounding environment. Harmony is sought after by trying to accomplish a safe and pleasant a trip as possible, both concerning the vessel itself, its crew, cargo and or passengers. The concept of harmony takes different forms depending on in which context the ship is at present (see Fig. 1). From requiring a larger effort while manoeuvring in the harbour to a more monitoring form requiring less effort in open sea. At sea, this is subject to change as the weather changes requiring more effort, equal to the level of effort in the harbour. The aforementioned effort consists of the core category harmony which consists of factors used by the shiphandler to successfully manoeuvre the ship. The sub-category of environmental prerequisites is formed by the factors context and situation. The sub-category of vessel specific prerequisites is made up by the factors inertia and equipment for navigation. The sub-category of personal prerequisites is formed by the factors spatial awareness, theoretical knowledge and experience (see Fig. 2).

Fig. 2 The constituents of effort to achieve harmony compiled of the seven factors and the three sub-categories



3.1 Environmental prerequisites

The sub-category denoted environmental prerequisites concerns external factors affecting the environment in which the shiphandler is manoeuvring his ship. The sub-category of environmental prerequisites consists of the following two factors;

3.1.1 Context

Every manoeuvre takes place in a context. This refers to the factors with static nature for a given space and time. These are the physical restrictions, i.e. the geographical setting. At open sea this is of less concern as opposed to being close to a coastline, inshore or in a harbour. In these contexts, there is the restricting factor of available space; the density of the archipelago, the width of the fairway, available water etc. These do all restrict the space available for manoeuvring. When you get closer to your designated berth the shape and size of the harbour, together with other man made constructions such as buoys, piers, pillars, cranes hanging out over the water and other moored vessels add up to objects that have to be accounted for when manoeuvring.

3.1.2 Situation

In any given context, there are situational factors acting upon the ship. These refer to the factors of a dynamic nature such as the weather and time of day. Factors concerning the weather are wind (direction and speed), waves (direction and speed), current (direction and speed) and visibility. These factors and their magnitudes affect each other in different ways. Wind generates waves and current in a direction opposing the wind make for rougher seas. The wind also generates drift of the ship and current affect the manoeuvring in a specific manner as the whole water in which the vessel is sailing is moving, taking the vessel with it. Visibility concerns the viewing distance and can be affected by rain, snow and fog. Time of day accounts for if the sailing takes place during day- or night-time, i.e. in light or darkness and if the sun is low and blinding. All these situational factors affect the situation in which the shiphandler has to act.

3.2 Vessel specific prerequisites

The sub-category denoted vessel specific prerequisites consist of factors relating to the specifics of the vessel—the tools available for the operator. Within these are factors affecting the manoeuvring characteristics of the ship, i.e. factors that cannot be influenced by the mariner himself.

3.2.1 Inertia

The ship's construction and design directly affects its manoeuvrability. All ships have a high level of inertia compared to other types of land-based vehicles. The factors noted here are those that have a direct effect on its experienced inertia. These are amongst others the size, both physical and displacement, and their interrelationship directly affect the way the ship behaves. Length and beam; the aspect of length versus width concerns how easy the ship stays on its intended course. The shape of the hull beneath the waterline affects its susceptibility to drifting and squat. The physical area above the waterline, the area of windage, also concerns the ships susceptibility to drift. The type of propulsion and main engine power vs. displacement ratio together with type of steering, rudder and thrusters, their quantity, placement and power all affects the manoeuvring characteristics of the ship.

3.2.2 Utilization of available instrumentation

The level of navigational instruments available to the bridge crew determines how they conduct their work. On a ship equipped with a low level of navigational instruments the bridge crew has to rely on more basic navigational methods with lesser instrumental feedback. A modern, well functional high-end integrated bridge system offers several means to both manoeuvre and to follow-up on actions taken.

3.3 Personal prerequisites

This sub-category denoted personal prerequisites, consists of factors relating to the shiphandler's personal ability to achieve harmony. Factors which, to a larger extent, can be controlled by the crew compared to those of the core category environmental prerequisites. Personal prerequisites are formed by the factors spatial awareness, theoretical knowledge and experience, presented below.

3.3.1 Spatial awareness

To be successful in manoeuvring the ship, the shiphandler has to master the ability to comprehend the surrounding world in both time and space. This refers to, for example, the ability to see and detect movement and to predict ones future position in relation to waves and objects. In close manoeuvring and in the archipelago, this is, to a large extent, a visual task using objects in the surrounding as reference while out at sea, under rough conditions, it is manifested as being able to feel and interpret different physical motions, to "read" the sea to be able to steer the ship as smooth as possible through the high seas.

3.3.2 Theoretical knowledge

Theoretical knowledge regarding manoeuvring is acquired through education. This concerns an understanding of the physical forces acting on the ship as a result of design parameters of the ship as stated in Section 3.2.1. It also incorporates knowledge regarding the effects of the ship interacting with the environment such as understanding of the effects of bank, squat and interaction.

3.3.3 Experience

Practical knowledge is mainly acquired in the real setting, although today there is also the possibility to train specific scenarios in simulators on shore. Practical knowledge is about spending time on the ship acting out your role of profession. Experience can both be of a more general kind; spending time at sea in different situations, or more specific, i.e. experience on a specific ship in specific situations.

4 Discussion

The Swedish archipelago is dense with very confined waters compared to many other geographical locations. This results in complex operations of manoeuvring which further stresses the need for high proficiency regarding ship manoeuvring.

The main finding from this study was that the shiphandler strives for harmony between his ship and the environment. Harmony could be related to the more common concept of control, see for example Hollnagel (2002); however, we argue for their difference. In our view harmony incorporates control whereas control does not necessarily result in harmony. The shiphandler can sail the ship with control but without achieving harmony with the environmental factors acting on the ship. With this knowledge, it is easy to understand the reason for the anxiety felt by the shiphandler when removed from the control of the ships manoeuvring task by a technical system (Okazaki et al. 2009). The technical system in this case significantly reduces the shiphandler's time for action, should an error occur, and thereby preventing them in their search for harmony with the ship movements.

Harmony was divided into the three sub-categories; environmental-, vessel specific- and personal prerequisites. This is in line with what Martin et al. (1998) suggests as factors contributing to the skill of shiphandling. These include the ability to judge the relative motion of the ship to be able to make predictions of its future state and to counteract with the forces of nature acting on the ship with course and speed adjustments. Martin's findings can be directly related to our results of the sub-categories of environmental- and vessel specific prerequisites, consisting of contextual- (static), situational (dynamic) factors, inertia and the navigational instruments. The last two factors together make up for the characteristics of the ship. These must then be balanced and acted upon by the bridge crew through the factors found under the sub-category personal prerequisites concerning spatial awareness, theoretical knowledge and experience.

The fact that perceptual abilities (in our results; the factor of spatial awareness) seem to be a big part of the manoeuvring of ships. This can be related back to what Brogdon (2001) and Crenshaw (1975) suggests as the possession of seaman's eye. Although no data was found supporting the earlier findings regarding contribution of proprioceptive input to ship manoeuvring (Prison et al. 2009). The importance of theoretical knowledge and experience can be traced back to previous work expressing worries over that trainees are given less and less time for practical experience, stressing the need for "on the job" training (Baillie 1997; Hunt 1997). This is further strengthened by Roberts (1997) who discusses the skills needed to be successful in the profession of commanding a ship. He argues that certificates of competence today are mainly proof of theoretical knowledge and that the real skills needed can only be acquired by experience. This is further addressed by Lützhöft and Nyce (2006) and Drahos (1997) in studying pilot training, stating that the "best practice" for the trade would be to put a large emphasize on the practical aspect of the education

The results acknowledged the division of the sea voyage into three contextual parts; close manoeuvring, archipelago and open sea. Further, results also showed that under normal circumstances the effort on the bridge crew differs between these three contexts by putting different levels of complexity on the shiphandler. Although, the fact that the maritime domain is dynamic, situational factors might also change for a certain geographic location (context) for different periods of time thereby changing the effort of the shiphandler to remain in harmony. This is, for example, the result of the normally low level effort of the context of the open sea turning into a situation demanding a much higher effort as in bad weather (see Fig. 1). This is in line with Fuller's driver task model (Fuller 2005) where the driver has to balance the dynamic changes in task difficulty. It is also connected to early findings as those of Gibson and Crooks (1938) regarding vehicle driving where the driver has to modify his locomotion as the field of safe travel changes as obstacles interfere with the boundaries of the field.

The importance of context can be directly related to studying human behaviour in its context. There are several theories stating that, studying human performance cannot be done without addressing the context, such as the theories of Naturalistic Decision Making, see for example Zsambok and Klein (1997) and Cognitive Systems Engineering (CSE), (Hollnagel and Woods 1983). Incorporated in CSE is the shift from studying the internal functions of the individual parts of a system one by one to the larger view of the external in a Joint Cognitive System (JCS) functioning in an environment (Hollnagel 2002). It would be feasible to incorporate the findings from this study into the framework of the JCS-model as they seem to fit into the model's division of factors between the JCS itself and factors belonging to the environment.

The concept of harmony in relation to the three levels of Situation Awareness (SA) as proposed by Endsley (1995) can be described as SA level 1 consisting of the environmental prerequisites and the spatial awareness factor of the personal prerequisites. To reach level 2 in SA, ship prerequisites and the factors of theoretical knowledge and experience of the personal prerequisites has to be added. Altogether, it reaches the third level of SA, enabling a projection of the ships' future status.

Elaborating upon Fig. 1, there seem to be a fixed theoretical room for action for a certain given situation in the different contexts; close manoeuvring, archipelago and open sea. The degree to which the shiphandler can utilize this theoretical room for action is dependent of the personal capabilities of the shiphandler, i.e. those listed under the sub-category of personal prerequisites, resulting in an available room for action. Depending on the level of ship sense the operator have certain available room for action to utilize in his strive for harmony between his ship and the environment he is currently acting in. This is in line with Fuller's TCI model: the driving task demands are balanced by the driver's capability to achieve control over the situation (Fuller 2005). Depending of level of ship sense one might not be able to balance these two out; not acquiring control over the situation, a situation which might end in an accident. With a higher level of ship sense, one might acquire control, or if being an expert and having a high level of ship sense one might reach the higher goal of harmony.

As stated by Crenshaw (1975), proficiency in shiphandling is reached through, apart from knowledge and understanding of the physical forces acting on the ship, practical hands-on experience on board practicing manoeuvres. He argues that hands-on experience is needed to be able to make correct judgements, anticipate how actions taken will affect the future state of the ship. This opens up for the hypothesis that practical training in manoeuvring of ships at an earlier stage in the professional career or from earlier experience might result in a more rapid acquisition of ship sense.

The greater understanding of the factors used by the shiphandler when manoeuvring the ship might give way to several future applications for the maritime domain. Training can be developed to better account for the important factors associated with ship manoeuvring and the relation between training in theory and in practice might be strengthened further. It can also imply the need for organisational changes on board to better incorporate junior officers in duties otherwise run by senior officers. As of today, becoming commander of a ship can take rather sudden forms of initiation regarding manoeuvring duties, as it is hard to find time for on the job training (House 2007; Hunt 1997). New educational modules addressing these issues might be a solution to this problem. Further, there might be environmental benefits by teaching junior officers to strive for harmony, thereby resulting in a more fluent behaviour while manoeuvring the ship instead of working the engine hard to get the same final result.

4.1 Methodology discussion

The participants were all master mariners and pilots recruited from a specific geographical area in Sweden, which might have implied a geographical bias. Therefore, there are reasons to propose a geographically broader sample of participants for future studies to account for different manoeuvring contexts and cultural differences. This was partly accounted for by the fact that all participants had experience from different geographical locations and manoeuvring operations. This comes with the trade of the merchant navy—mariners sail the seas and perform all the associated operations at different locations worldwide. This also accounts for the pilots who all have previous assignments as master mariners in the merchant navy. The fact that the local pilots, participating in the study, are not just assigned to the local area but also operate other regional locations on the Swedish west coast also account for a distribution of operational context.

The reason for the method of choice was partly that of difficulty finding relevant participants and partly the need for participants with a personal interest in the topic, making them a better fit for the study.

Regarding the relatively small number of participants it reflects the problem of getting hold of mariners for participation in research studies. Their working schedules make them hard to get access to, in order to compare to non-mariners. Mariners on leave are also less prone to participate in research when not in service. Further, the available number of participants where narrowed even further due to the restrictions on homogeneity. Despite these restrictions, a level of saturation was found in our collected data (Corbin and Strauss 2008).

The reason for the use of Grounded Theory was foremost the exploratory approach taken and the method being inductive. The method also allows for the researcher to hold previous domain knowledge. The method further strengthens the researcher's sensitivity of understanding the results collected (Corbin and Strauss 2008) with regards to the researchers own background. The structure of the method further addresses this fact.

The current study focused on the individual shiphandler, not the bridge crew as a team. In future studies, it might be valid to study the whole bridge crew as a team regarding shiphandling. Future considerations could include: is what we have labelled ship sense possible to mediate? What is it that is mediated? How should it be mediated?

5 Conclusion

The main findings consist of two parts; the division of the voyage into its three phases regarding the manoeuvring of the ship and the fact that these require different levels of effort from the shiphandler in order to fulfil the second main finding; the strive for harmony between the ship and its environmental factors.

The three phases; close manoeuvring, archipelago and open sea consists of the same environmental prerequisites, but their individual degree of influence upon striving for harmony by the shiphandler varies. To achieve harmony, the shiphandler has to balance the effects of the three found categories environmental prerequisites and vessel specific prerequisites with personal prerequisites.

As ship sense seem to partly consist of tacit knowledge it would be feasible to complement the results from this study with future studies specifically designed for expert knowledge elicitation, such as Applied Cognitive Task Analysis (Militello et al. 1997). This might also reveal the differences in manoeuvring performance between expert and novice shiphandlers.

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