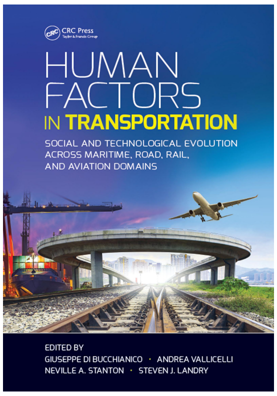

Human Factors in Transportation
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Seeking Harmony in Shore-Based Unmanned Ship Handling: From the Perspective of Human Factors, What Is the Difference We Need to Focus on from Being Onboard to Onshore?

Yemao Man, Monica Lundh, and Thomas Porathe

CONTENTS

6.1 Introduction

During the ship handling process, ship handlers have always strived for a continuous balanced effect by tuning the ship to the environment under different situations. Previous studies (Prison et al., 2009) have discovered that one tacit but indispensable gut feeling known as ship sense is intensively involved in ship handling for the safety of the vessel and people. When the bridge officer lacks visual reference, navigational instruments like the radar and the electronic nautical chart will be the main input source. However, when the weather gets rough, he will make use of ship sense to handle the ship in relation to the direction of the oncoming wave (Porathe et al., 2014). Sensing the ship's movements, the bridge crew will maneuver the ship to achieve the goal of safety.

Ship sense has never been the magic word from the perspective of perception and cognition. During the ship's maneuvering, information will first be gathered through the ship handlers' senses via different perception receptors. For example, the information could be the kinetic feeling of heaving, pitching, and vibration of the vessel, seeing the wave patterns, hearing the wind, wave slamming, engine sound (Prison et al., 2009), etc. Then the ship handler has to interpret the information and make sense of the situation with the mental model. By using his experience and skills, he will eventually make a decision. Since the dynamic information comes from the environment and the vessel whose physical state is constantly changing, the ship handler has to cope with fast-emerging tasks, such as slowing down the speed or adjusting the rate of turn when feeling the bank suction effect. Effective decision making and appropriate actions from personnel can only be achieved by successfully balancing task demands and the human's individual capabilities (Fuller, 2000). In the task of ship handling, there is a balancing act between the ship handler's capabilities (based on his personal prerequisites) and the task demand (made up by the environmental prerequisites) conducted through his vessel (the tool) (Prison, 2013). That is the "harmony" between the ship and environment that ship sense serves to continuously assure safety (Prison et al., 2013).

While the concept of ship sense and harmony is originally created for onboard ship maneuvering, this chapter extends it to the domain of shore-based unmanned ship monitoring and control from the perspective of changes in human factors. The 3-year 7th Framework EU Project MUNIN (Maritime Unmanned Ship through Intelligence in Networks) has been investigating the feasibility of autonomous unmanned ship and prototype implementation of its shore-based control center (SCC) since 2012. The motivation for MUNIN is presented as the striving for a better working environment, reducing costs of transportation, the global need of reducing emissions, and increased safety in shipping (Porathe et al., 2014).

In MUNIN, the unmanned ship is one 200 m long dry bulk carrier with the intelligent Autonomous Ship Controller (ASC) system. The slow-steaming ship conducts collision avoidance without human interference during intercontinental voyages. Meanwhile, the ship is also constantly monitored by a manned SCC. The operations in SCC includes remote monitoring and remote control (Rødseth et al., 2013), so SCC can decide when to intervene based on the status information sent from the ship, and also override ASC to make sure the ship is working under International Regulations for Preventing Collisions at Sea (COLREGS).

With the apparent changes made in the system, people are no longer maneuvering ship onboard but from ashore. Nowadays, the maritime industry is facing more human factor issues (Han and Ding, 2013). Unmanned ship might resolve fatigue problems but it also brings more questions concerning remote supervisory monitoring, as people need to be able to get into the control loop at any time. For example, how do operators in the SCC perceive the ship's movements and maneuver the ship without ship sense when the working environment has greatly changed in the SCC? There will be no physical connection between the human and the vessel, and no directly perceived information from the ship's environment. Specifically, the visual perception of the environment, a vital sense in ship handling for bridge officers, will be lost. The important questions will arise: Are there going to be new human factor issues? Will the same human factors be applied as they do for the manned ship? If no, what factors behind ship sense onboard need to be refactored to the shore side? How can we prioritize them to regain harmony?

In fact, the sense deprivation and new way of human machine interaction indicates the importance and necessity to reanalyze how human factors are applied in a distributed system. This chapter provides a preliminary exploration of human factor issues in shore-based unmanned ship handling and explores some influential aspects of human factors we need to focus on in order to facilitate shore-based ship handlers to regain harmony. Ten master mariner program students with experience at sea were invited to take part in a focus group interview. The purpose is to discuss the different tasks and actions onboard and ashore as a basis to explore underlying human factors requirements in the context of the MUNIN project. The results highlight several differential aspects in human factors that should be considered, refactored, and prioritized. It also suggests general approaches to user-centered design for SCC in practice.

6.2 Methodology

The study adopts the focus group interview (Kitzinger, 1995) as the main data collection approach. Ten undergraduate students in Chalmers University of Technology voluntarily took part in the focus group interview. The participants' background was similar: they were studying in the same master mariner's program and they all had sea experience prior to the focus group interview, however, not as officers. Their previous active time at sea varied between 9 and 33 months, average 16.5 months (the standard deviation is 7.2). Only one participant was Mexican-Swedish while the rest nine participants were all Swedish. Their ages range from 22 to 41 years old, average 27 years old (the standard deviation is 7.2). One of the participants was female (10%) while the rest were males (90%). Out of the 10 participants, only one person (10%) did not have ship maneuvering and navigation experience, the rest (90%) all had experience in ship handling from the bridge, either alone or under the supervision of the captain. Fifty percent of the participants had the experience of remote ship monitoring or controlling, including in a simulation environment. Besides, 50% of the participants had been previously involved in ship or workplace design work (ships, systems, tools). Forty percent of the participants mentioned that they also had working experience in maritime-related activities at the same time as they studied, mainly being able seaman and working for passenger vessels.

The focus group interview took place at Chalmers University of Technology, Gothenburg, Sweden. All participants signed a written consent about the anonymous and ethical usage of their data in the academic research. The interview process was recorded by a voice recorder for further analysis after the interview. The interview lasted for approximately 2 h. The focus group interview assistant took field notes on the participants' discussion. All participants were briefed about the MUNIN project with the idea of a dry bulk carrier sailing without a helmsman by remote ship monitoring and control. The discussion was based on the constraints and conditions in the project described earlier in this chapter.

The first questions asked the participants to discuss the possible actions to execute ship handling that would actually correlate with their past ship maneuvering experience: *What actions will it take to monitor and maneuver the ship onboard today?*

The replies from the participants were continually listed on the whiteboard. Then the second question asked the participants to envision an operators' possible action in an SCC: *What actions will it take to monitor and maneuver an autonomous unmanned ship from an SCC?*

With the actions and tasks being discussed in both onboard and onshore situations, the third question asked the participants to identify the changing aspects of human factors under these two circumstances: *From the perspective of human factors, what is the difference when we shift ship handling from being onboard to being onshore?*

Finally, the participants were asked to prioritize the key aspects of the human factors that would require special attention, especially in terms of designing work for the SCC.

After the focus group interview, the ordering scheme for the data with prioritized feature lists was initially created and summarized. Then the lightweight qualitative data analysis approach (Goodman et al. 2012) was taken through by analyzing the audio recordings together with the field notes as well as the lists.

6.3 Results

Based on each participant's own experience, the replies to Question 1 were as follows:

- Checking screen, radars, conning display, AIS for maneuvering
- Looking outside the window (to get a feel for weather, wind, speed)
- Feeling the sense of balance
- Feeling waves, rolling, pitching
- Getting an intuitive feeling of what the needs are and being less stressful
- Feeling the ship (e.g., the ship's performance when cargo is loaded, how the ship's sensitivity is when turning)

The majority of participants mentioned that they would use the navigational instruments in the bridge to see the status of the ship and the surrounding environment, for example, "checking screens," "radar," "conning display," or "AIS" to make sure the ship was safe. However the most discussed key word was "feelings" that they perceived by looking outside of the window and experiencing "standing wave," "rolling," or "sense of balance" with the vessel. The participants thought this was one important intuitive sense that kept their stress levels down and even helped them to take corresponding actions more efficiently with regard to the external environment, because "body reacted quicker than the instruments." In terms of maneuvering, they thought one important aspect of the feelings was to sense their ship, for example, "feeling the sensitivity of the ship" or "feeling the ship's performance when cargo is fully loaded or not."

When the discussion turned to remote supervisory monitoring (i.e., Question 2), the participants envisaged what the operators in the shore control center would probably do, but they suggested it was an unprecedented challenge for which they did not have a perfect solution (see Table 6.1).

Basically the actions that operators can do ashore were to observe the screens and perceive dynamic real-time information. Multiple human–machine interfaces ashore was discussed compared to onboard ship handling. Most participants deemed the simulator as the ideal human–machines interface used in the shore control center, as "They don't want a mouse button but a joystick handle." In terms of sense, they anticipated there would be gyros and other senses that could simulate the feelings onboard. As more assumptions were proposed in the focus interview, the participants turned to list the leading consequences being onshore as the unprecedented challenges, for example, maintenance work, economy cost, reliability of the system, etc. Meanwhile, the participants realized that "not the same human factors were needed" in both situations, the discussion moved on naturally to the main research interest of the interview (i.e., Question 3). The overview of the replies was presented in Table 6.2.

From the perspective of the majority of the participants, the most controversial question they would consider in priority was the possibility to build a "the full-proof system,"

TABLE 6.1

Actions and Confronted Challenges Discussion Concerning Shore-Based Ship Monitoring and Controlling

What the Operators Would Do	Consequences as Challenges
Observe multiple screens	It must be possible to display all-needed information and allow perceiving it as onboard but it would cause information overloading problem;
Use simulator as human–machine interfaces rather than mouse/keyboards	The operators must be considered as seafarers with expertise
Monitor incidents onboard Well prepare for emergency	How to handle maintenance work immediately and management (ordering spare parts)
Observe gyro and other sensors	Are they real-time sensors, if so, what the cost would be
Let system calculate risks and alternatives	Ensure more backup sensors and systems on the ship to prevent/handle severe technical failure (e.g., connection lost)
Trust in the system and sensors	How to guarantee the reliability of the system so people could really trust it

because they believed that it could be a big risk to solely rely on the shore-based monitoring system and therefore judge things from it. Except for the skepticism, they explicitly mentioned situation awareness as the most significant key to focus on when shifting ship handling from ship to shore followed by information overloading and organizational issues.

TABLE 6.2

Overview of Changing Human Factors from Ship to Shore for Ship Handling

Human Factors	Presentation of These Factors	Voices
Sense	Visual, auditory, sense of smell, kinetic feeling, sense of balance	*"Ship starts vibrating and pitching when changing the course a bit, but these senses are lost ashore."* *"Everything got closer ashore."*
Perception—cognition	Mental model, decision making, situation awareness, information overloading, stress, trust in the system	*"You may pay attention to parameters that don't matter or are wrong and you worry for nothing."* *"Receiving much more information but you can't discern what matters to you as you did onboard."* *"When you're onboard, fear is stimulating but you're less stressed ashore. Complacency. Maybe too relaxed."*
Work space	Working environment, ergonomics, hardware, software	*"Only rely on instruments ashore."*
Maintenance	Backup systems, maintaining approaches	*"A big part of the ship work is maintenance."* *"What happens if there is a malfunction or emergency?"*
Risk	Risk assessment, shifting risk	*"Risks for other boats around."* *"Not that risky being onshore."*
Organization	Expertise, structure, roles, education/training	*"Computer engineers for the operator ashore would be good since they monitor ships through computers. Seafarers would not need that"*
Legal perspective	Regulations, laws	*"Who is responsible if the ship is in international waters?"*

6.4 Discussion

The focus group is used as the data collection method and is also used partially for the data analysis in this research. The reason to choose the focus group is because it is suitable for identifying problems, seeking to solve problems from the stakeholders' view with an exploratory research manner (Ivey, 2011). More importantly, it can provide insights into the sources of complex behaviors and motivations (Morgan and Krueger, 1993). The purpose of this research is to explore the key aspects of human factors with regard to maintain ship sense when shifting people from onboard maneuvering to shore-based monitoring. The target audience are fourth year master mariner program students with a certain amount of navigational experience at sea. The average age is 27 years and they are comfortable using a daily digitalized device, for example, laptop, iPad, iPhone, etc. Therefore the focus group can provide multifaceted opinions by looking deeper into their working experience and maneuvering behaviors, and seek the affected human factors behind the explorative computerized solution in the SCC. Although the focus group cannot substitute a usability test and observation of the product in use to evaluate how efficiently people will use a certain product, it can underpin the research of human factors in complex systems and provide values on which design direction would be widely accepted.

Designing a focus group interview elaborately to ensure its structure is vital (Morgan, 1996) so the moderator controlled the topics to be discussed step by step and involved each individual participant as equally as it could. Following the discussion that went from actions onboard to ashore, a comparative analysis was conducted during the interview. It might not provide the "full picture" to all aspects that need to be covered within 2 h, but it indeed afforded valuable insights on some discernible "tips of the submerged iceberg," such as how the perception difference might shape the operators' behaviors in the SCC, and what the main factors were that hindered them from achieving a high level of situation awareness.

However, the focus group has limitations like other forms of data collection. First it is not a statistically significant sample (Goodman et al., 2012). Although the group participants have sea experience, they are far from experienced seafarers. None of them are bridge officers. Second, those whose viewpoint is a minority perspective may not be inclined to speak up or risk negative reactions (Patton, 2002). Besides, there are no fully fledged proven solutions to be provided to the participants, thus it is hard to envisage what the SCC would look like at the end of the day. After all, in the exploration-oriented group discussion, the lack of the reference frame may lead the participants to some "limbo" state and therefore affect the discussion results. There is also one possibility that the participants see the autonomous unmanned ship as one potential conflict with their career development, which might partially explain why the discussion was at once deviated to the unfeasibility of the whole concept.

The result from actions onboard provided by the participants indicates that "feeling" is very important in ship maneuvering. This tacit and gut feeling is interpreted as the ship sense which is seen as critical for seafarers in ship maneuvering (Prison et al., 2009). Such feelings are strongly related to the kinetics that can give the bridge crew vital information in a more straightforward manner than the instrument screens: how the ship is behaving now and under what circumstances. It means the sensitivity that the ship presents when reacting to the external environment (e.g., how the ship is reacting to the bank suction effect) and internal status (e.g., full cargo or not), as well as the constraints from the environment (e.g., weather, wind, wave) that the bridge crew must take into account in ship handling. Visual perception has significant weight in all the sensations. Ship status can be read and judged from the screens in the bridge in combination with the environment information that can be gained by looking outside. Figure 6.1 presents the analysis results on how seafarers get visual information from navigational instruments while perceiving feedback coming from the environment and the movement of the vessel.

From the perspective of human–machine interaction, the seafarers are constantly "interacting" with both the vessel and the environment. Although the participants were more stressed under such circumstances, they expressed that they have the ability to discern the priority of information and act intuitively. However, the ability would become inability when people are located far away from the conducted vessel in a shore-based center. There will be no physical connection between the human and the vessel, and no directly perceived information from the ship's environment. Specifically the visual perception and the kinetic feeling will be lost, which would truly jeopardize ship sense.

The participants acknowledged that operating ashore would put the inevitable "feeling" in jeopardy, "the connection with the outside world is lost," and therefore they proposed many ways to compensate such feelings or substitute such feelings in their replies. Some participants went for the simulation setup or for visualization solutions so that the SCC could mimic the ship sense. One typical suggestion is to use the simulator as human–machine interface, consequently the bridge crew can see the surrounded 3D (three-dimensional) visualized environment, provided that the sensors can transfer sensory information to shore in real time. One of the critical concerns is that visualization might not be able to provide enough situation awareness. For example, it does not

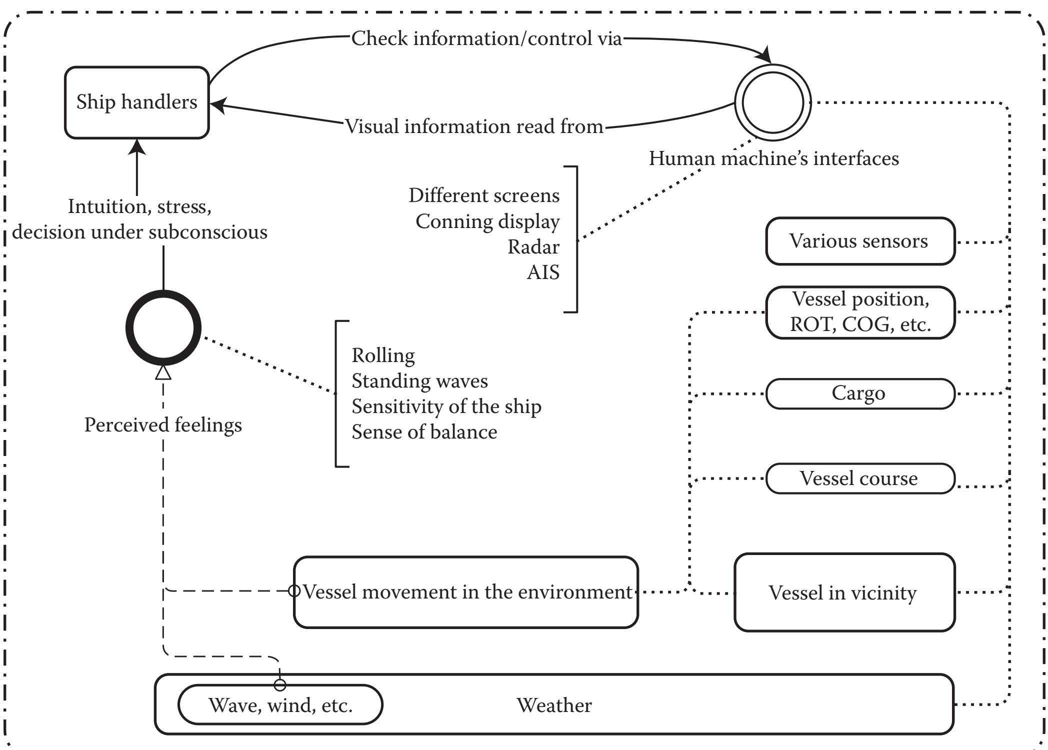

FIGURE 6.1
Ship handlers gain visual information from bridge instruments while perceiving feedback coming from the environment and the movement of the vessel.

resolve the problem caused by the loss of motion, as people do not move with the ship any more as they do onboard, thus they are not able to feel the tool they are operating. Some other participants turned to the sensors to seek alternatives for ship sense, as gyros can tell vibration, roll, and heave. However, there are also usability issues as too much visual information might cause information overloading for the operators ashore.

With the previous discussion (treating onboard and onshore situations separately) as the underpinning blocks, the participants seemed to understand the topic more comprehensively and had contributed something more valuable in Table 6.2—there are indeed several identified aspects of these changes in human factors that we must not ignore when shifting navigation from ship to shore. Except for the skepticism, the participants listed situation awareness as the most significant key to focus on. Situation awareness stands for three levels of information processing: perceiving information, understanding information, and anticipating information (Endsley, 1988). When fulfilling the task of maneuvering, the information is gathered through seafarers' senses via different perception receptors like the retina, which indicates the first level of situation awareness. Previous studies (Endsley, 1995) find that attention and working memory are the critical factors when people are interpreting things from the environment into their mind. The concern from the participants perfectly match these critical factors in situation awareness, for example, "you may pay attention to parameters that don't matter or are wrong and you worry for nothing," and the notorious "information overloading" problem.

The mental model is seen as an important sense-making tool to overcome such limits and decide the priority of information (Endsley, 2011). The participants felt that the monitoring process was generally full of "complacency and relaxation," until the occurrence of unexpected automation failures. "Receiving much more information but you can't discern what matters to you as you did onboard." It suggests the emerging challenges caused by degraded situation awareness and partial sensory deprivation ashore. It also indicates that operators who were assumed to be bridge officers need to develop new mental models as a higher level situation awareness enables the adaption to the working pattern ashore. Maintaining situation awareness would be even more challenging than achieving a certain level of situation awareness since it needs to keep users in the loop of the dynamic situation (Endsley, 2011).

Along with the described issues with respect to perception and cognition, the organizational problem is also considered as one prioritized aspect in the development of a shore control center. It raises questions like, what the role of the operators should be, what the difference would be compared with seafarers today, what regulations or rules were needed, how the training program should be tailored for them, etc. The puzzle needs to be solved from multifaceted views.

Noticeably, maintenance is identified as one of most serious issues with no one onboard. It explained partially why participants asked for backup solutions in a full-proof system in the first place. The trust from the operators is there only because of the reliability, resilience, and robustness of the system. However, there is hardly confirmed evidence to prove that an unmanned autonomous ship could function with "fail-safe" guarantee during the whole voyage. Could it even be managed by the shore-based operators at any time, the majority of the participants held a skeptical attitude toward the concept of an autonomous unmanned ship. Along with the LinkedIn group discussion (Unmanned Ships on the Horizon, 2014), there has always been a problem with the acceptance of the concept of an autonomous unmanned ship. The goal of the MUNIN project is not only to study the feasibility of an unmanned ship and SCC, but also to aim at improving sensor systems, cooperation work flow between ship and shore, maintenance procedures, and reliability and cost-effectiveness. Those studies and research may also be used in the future concept that only partially removes seafarers from ship to shore and makes the maritime industry more attractive and safer. Some key human factors onboard influencing safety have been identified, such as fatigue, automation, situation awareness, communication, decision making, and teamwork (Hetherington et al., 2006). Automation is often introduced to reduce human error and work load, but it also shapes crew assessments and actions (Lützhöft and Dekker, 2002). Automation surely cannot simply replace human work with machine work and MUNIN is just a first step towards a distributed human-centered automation framework for deep sea voyages. It provided opportunities to explore the different presentation formalities and facades of known human factors along with other emerging challenges under one new business model in the maritime domain.

6.5 Conclusions

The results from the focus group indicate the gap between the tasks that require adequate situation awareness to maintain ship sense and the inability of personnel ashore to do this due to the lack of conventional sensory cues and appropriate organizational regulations and management for SCC. The original “harmony” faces new challenges by reconstructing its constituents (Prison, 2013), that is, people, vessel, and environment. Ship handlers still strive for a continuous balanced effect by tuning the ship to the environment, but in the remote control pattern. On the one hand it might bring more risks in operations due to the lack of situation awareness and thus put harmony in jeopardy, but on the other hand, it suggests the approach to design an integrated system by studying the changes in various aspects of underpinning human factors. Through the deep analysis in the contextual nature of the onboard and shore-based environment, the intrinsic variability of those applied human factors can be exposed for further human factors refactoring. What is going on ashore, how it is different, and how it can be adapted to humans, the explorative research in the future unmanned ship presents to the industry unprecedented challenges as well as endless opportunities.

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