Situation Awareness in Remote Operation of Autonomous Ships

Shore Control Center Guidelines

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ABSTRACT

The introduction of remote operation of autonomous ships comprises a new set of challenges regarding operator Situation Awareness. To gain a sufficient understanding and a clear picture of the situation of multiple autonomous vessels in open water, a simplified and clear presentation of data, which creates a reliable human/autonomy symbiosis, must be developed. By using established situation awareness principles from navigation and similar information rich operator situations, a set of guidelines have been developed in order to support the design process of the operator's environment through reduction of obstacles in situation awareness generation and compensation for human limitations. Applying these guidelines has a potential of creating a safer and less cognitively demanding workstation that enables a higher level of situation awareness for the remotely located operator.

KEYWORDS: Situation Awareness, Remote Autonomous Ship Operation, Human Performance, User Interface Guidelines

1. INTRODUCTION

Shipping is the most energy efficient means of transportation in the modern society. The growing global economy demands an equal growth in efficient shipping. In a world with an increasing environmental focus, measures will have to be taken to not only reduce the carbon footprint but also reducing the risk of human error leading to undesired environmental impacts. The attractiveness of seafaring is declining and with plans of further reducing sailing speeds [1], recruiting new workers to the longer voyages is becoming even more challenging and the costs of keeping them onboard are even higher. The lower sailing speeds are demanding more ships, which further escalate the situation. A way of solving this challenge is the introduction of autonomous unmanned ships, which removes the limitations of the on-board crew. This will also make room for even more cargo as the hotel facilities are completely removed. With such a concept comes a new set of unanswered questions. A modern ship bridge is currently not developed to the desired level of Situation Awareness, and if perceiving and utilizing the right information in hectic open water scenarios was not enough, the industry along with EU and several university institutions is working towards moving the captain's responsibility form the bridge to shore based control centers[2-5]. How can an operator with the limitations of high data-costs, low bandwidth and remote sensory input successfully operate merchant vessels in open waters? An increased level of ship autonomy will support the operator, but the aim to operate as much as 10 ships simultaneously[2] is challenging the human limitations.

This article addresses the Situation Awareness related aspects of remotely operating autonomous merchant vessels in open water to establish a set of design guidelines for developing safe and reliable shore control. Remote control of autonomous vessels is a fresh and underdeveloped field, so the majority of the research supporting this article will be gathered from the MUNIN project and studies on similar situations in fields with workloads and challenges that can be related to the remote operation of multiple autonomous vessels.

2. SITUATION AWARENESS

Situation Awareness is formally defined as a person's «perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future» [6] This definition breaks down to three levels [7]:

Level 1 - perception of the elements in the environment
Level 2 - comprehension of the current situation
Level 3 - projection of future states

Situation awareness is a constantly evolving picture of the environment. Parallels can be drawn between what happens in a flight cockpit, a nuclear plant control room, behind the sticks of a military UAV or at a marine Shore Control Center (SCC). These are all complex and dynamic environments with similar challenges where the information capped situations and high workloads can lead to human error. History shows that such accidents occur frequently, impacting both human lives and the environment. A more accurate term for the majority of these human errors would be design-induced errors as they are outside the operator's control[7, 8]. Poorly designed systems lead to incomplete and faulty pictures of actual situations that derail the operator's expectations by leaving him/her with the major task of bringing the failures and inefficiencies together[9]. Such errors should be handled at the drawing board.

"A non-integrated, systems-oriented presentation of information will exacerbate attention limitations, whereas a well-designed system will help compensate for them."[8] Working memory represents the primary bottleneck for Situation Awareness[10]. An individual can hold and manipulate 7, plus or minus 2, containers of unrelated information simultaneously[11]. We cannot change biological human limitations but design thinking can compensate for them by facilitating efficient dataflow through the bottleneck. Disorganized data and streams of text move slowly through our mental pipelines compared to graphical and sensible representations. The designer can utilize more suited parts of that brain to handle the presented complexity through advanced sensory activation and alternative information processing mechanisms. This will lighten the load on work-memory to keep operators up to speed whilst reducing the overall workload, directly reducing stress and fatigue. By simplifying the digestion of the available information (Level 1 SA), one can facilitate a better comprehension (Level 2 SA), and enhance the projection of future states (Level 3 SA). This have been shown to dramatically improve decision-making and performance for operators[7, 8]. The main obstacles in gaining a solid SA can be referred to as SA Demons [7]. The most important ones being:

Attention tunneling
WAFOS (requisite memory trap, Workload, anxiety, fatigue and other stressors)
Data overload
Misplaced salience
Complexity creep
Errant mental models
Out-of-the-loop syndrome
Minimizing these factors is crucial to a successful SA approach and this will be of high priority in the further analysis performed in this report.

3. SHORE CONTROL OF UNMANNED SHIPS

In order to obtain an accurate mental picture for up to 10 vessels at any point during a captain's watch, a simplified operational approach based on a human/ship-autonomy symbiosis must be developed. There is reason to believe that the ships, with current and further developed technology, will be capable of determining the best route for themselves and make suggestions or inform their operators as changes and challenges occur. Still, there is an important challenge regarding the amount of decision making being handled by the autonomous system. By letting the autonomy operate without human interference, the system is effectively handling a part of the overall workload but on the other hand, it is actively distorting the operator's mental picture by operating behind the curtains. Given a smart enough autonomy, this might be perfectly fine in most cases, but when the autonomy fails or reaches a situation it is not suited to handle, the operator is at high risk being out-of-the-loop and unable to detect the problem, properly interpret the available information and intervene in a timely manner[7].

Existing technology streamlines the basics of navigating a ship in open water. As there is no longer need for a direct control of the vessel under normal circumstances, the autopilot can potentially be controlled from shore. This indirect way of controlling the ship utilizes a minimum size of data but creates a bottleneck for the SA acquisition that is also kept at a minimum with the current information level of the map-centered, ECDIS approach. MUNIN presents tools for managing this obstacle. They have created a new approach to the ECDIS system that enables the operator to monitor and change the ship's route in an effective way whilst being provided essential information for this to happen in a situation aware manner. The idea of implementing visualizations of limitations to navigational aspects like turning radiuses (Figure 1) is a great way of enhancing the operators SA as the cognitive task of calculating the visually varying distances in a scalable and dynamic map are reduced. The information represents crucial SA elements, but the transition from this ECDIS centric control mode to egocentric manual control represents a major change in the work environment.

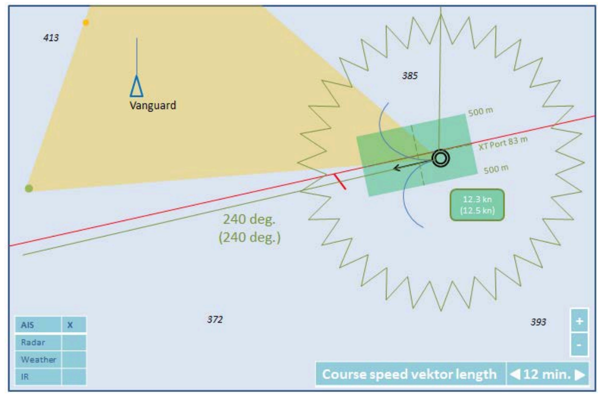

Figure 1[12]: Ship Limitations and "Safe Haven"

Voyage plan

By creating a geographically independent, remotely operated system, the captains will be able work across time zones. Motivated and rested operators can come to work close to their family and friends and operate the vessels during normal work-hours without the challenges of the traditional fatigue related to long seafarer watches. This strengthens their ability to stay fully alert at any given moment - securing higher performance and more effective SA acquisition. On the other hand, an operator starting his watch must be brought into the loop in an effective and seamless manner. This can be facilitated on an interpersonal level, but should be assisted by a clear and effective, transferrable picture of the current situation. The timelines that MUNIN have developed are presenting operational shifts and marks for upcoming tasks with ETA's and other important information in a simplified and informal way. These timelines are again connected to the ECDIS system, enabling geographical pins along the route to create a simplified visual understanding of the upcoming events. By knowing the ships position according to the ideal timeline, the system can create what MUNIN calls the "Safe Haven". This is a box surrounding the ship, illustrating where the ship should be in correlation with the planned route, facilitating an effective and cognitively efficient way of understanding the situation and creating a goal related understanding of current performance. This simplifies the process of staying in the loop with several ships simultaneously.

Information hierarchy

The timeline proposal will effectively break down the major pile of vessel information and ease this handover process, but detailed monitoring of every aspect of each individual ship and its advanced onboard systems comes with a large set of data. To simplify the monitoring, a standardized information hierarchy must be established. A challenge facing information systems is that directly available information is often, for various reasons, not observed or included in the scan pattern, forming the largest single casual factor for SA errors[8]. A human centered approach is crucial to overcome such obstacles so that the design solutions fit the capability of humans. This will result in reduced error, improved safety, improved user acceptance and satisfaction and finally improved productivity[7]. The MUNIN proposal is a monitoring interface where ships are flagged (Green/Yellow/Red) according to the status of their information hierarchy. This is a great architecture as a basis for designing a further developed interaction for operation. MUNIN's intended system uses Green flags for OK. However, the use of attention grabbing colors for steady states should be limited to reduce attention to aspects where no attention is needed.

Human Sensory challenges

"…there are two modes of cognitive processing. One is automatic, less capacity-limited, possibly parallel, invoked directly by stimulus input. The second requires conscious control, has severe capacity limitations, is possibly serial, and is invoked in response to internal goals." [13]

Being separated from the actual ships will limit the operator's Ship Sense[1] due to a lack of visual, auditory and haptic information about the ship's environment and state. The question here is how much sensory input the shore control center needs to recreate a sufficient SA. With modern technology comes endless possibilities of sensor applications that could be directly transferred to shore, but this raw data has a lower quality to the operator, as data traditionally collected unconsciously onboard has been translated into a more cognitive demanding format that represents another SA obstacle. By translating this data back into the initial sensible feedback one could recreate a lot of the awareness, but one should be careful not to create undesirable results like visual overload or motion sickness, either physically or visually induced.

Figure 2[1]: Pitch/Roll display

For the motion part, MUNIN suggests a solution based on the existing aviation approach to visual feedback from physical movements, where a circular display is giving feedback on pitch, roll etc. (Figure 2). This will give a simplified and valuable indication of the ships movement, but it is also a model that needs focused attention to function properly. This is why arguments can be made to whether or not this is enough to provide sufficient SA when it comes to the impact this movement has on both cargo and the ship itself, without impacting the capacity to stay up to speed with other important focus areas. Alternative approaches in creation of such feedback should be explored in order to address more natural human capabilities. A further developed system based on extensive sensor input could be provided through graphical clear representations with implementation of highly sensible solutions to achieve minimized work-memory utilization.

Multi-Person Operation

The shore control centers will, based on the MUNIN-concept, be team-based where each team consists of multiple operators, a supervisor/shift-leader and engineering support. The individual operator stations must be facilitated for operational, supervisory and engineering support during normal operation, in a way that supports each operator's sense of being the supreme commander of their vessels, as having a supervisor overlooking the operator's shoulder at any time will ad an additional stress factor to the operator. This will impact the ability to gain maximum SA during operation.

Multi-Ship Operation and "Carry-over effects"

With multiple ships in simultaneous operation, there is a high risk of "carry over effects". Aspects from the awareness of one ship's situation can be mistakenly carried over to other ships as they operate in similar situations and environments. The result is a faulty picture with a significant impact to decision-making and control.

Critical Situations

In order to facilitate a tailored platform for indirect control, the direct control of ships has been moved from this platform to situation rooms(REF) that will be used whenever indirect control is insufficient. The direct control will be a complete ship bridge like you would find in existing ships developed from the continuous design language present in the indirect platform, to facilitate seamless transitions and efficient utilization. Direct control is based on a significantly higher bandwidth usage with direct video-feed and control. In essence a simulator like we find in training facilities today, connected to the actual ship in need of direct human control.

Virtual and Augmented Reality

Current technology allows the ship's environment to be recreated in 3D on shore from real-time ship data. This can be done using no more data than the current strings sent to the shore control centers. By placing the ship into a simple 3D recreation of the world one can gain SA in a more natural and traditional way by developing an enhanced understanding of the 3D space surrounding the ship. This will facilitate for a smoother transition into an actual reality provided during direct control and other real time video transfers by reducing the psychological distance[12]. Studies in safety, security and rescue robotics show that sufficient SA is of such importance that operators will put everything on hold for an average of 30% of their time to do nothing but acquiring or re-acquiring SA, even during time-sensitive operations of search and rescue task[14]. If the time needed to gain real-time observed SA in the situation room can be reduced by providing this SA at an earlier stage, prior to the decision of utilizing the room, the operator will have a stronger decision-making basis upon entering the situation room. With all the 3D-oriented data available the next step would be to create an augmented reality for the operators during direct control.

From Concept to Reality

The automation/human relationship is a core factor of making the fundamental concept of autonomous ships work. There are a lot of challenges regarding security issues and system reliability that needs to be worked out, but in order to get the project on the right track, one must prove that the basic harmony between ship and operator is present and functional. Without a successful creation of such a symbiosis, the project will most likely remain at a conceptual level. This harmony is highly feasible from a technological approach, with the right tools and mindset, but the industry along with the important end-users must be convinced.

Most of the Shore Control Center information needs and challenges have been mapped out with varying approaches and solutions. The next step is to put this in the comprehendible and believable environment that gives the operators sufficient SA to safely operate a given number of vessels that industry and directives can trust and actually utilize in a safe and responsible way. The current control centers are presented as an unnatural environment for ship operation as the workstations are simple computer screens that draw direct parallels to a dull level of gaming. This is supporting much of the critique against shore control, fueling the forces working against the concept. Even though the information is mapped out in a task centric way with access to the important data, it still does not feel like a qualified substitute for traditional ship control. The reality is that this is a system primarily created for indirect control, which demands a significantly reduced number of physical controllers, but it can be hard for someone to imagine how these centers will actually work and especially how the system will work during critical situations as it is presented today.

With such a defined set of tasks ahead, a more dedicated center as a whole can be created. To make the system feasible from SA point of view, the UI must be a solid SA supporting vessel in itself. Gaining sufficient SA does not stop when the needed information is provided. The actual presentation of these elements is the most crucial part of the process that must be developed through testing and experimental mapping of the available data.

4. DESIGN GUIDELINES

Taming the demons

In order to create a successful shore control center the demons of SA must be tamed. The SA principles presented by Endsley [7] is an effective basis for doing so and will be used as a basis for the guidelines presented here.

Design of controls

The controls are the primary interaction between system and operator. In order for these to support efficient SA generation they need to be intuitive and task specific with a limited number of control states[15]. This limits the cognitive demand of both keeping track of current states and efficiently changing between states in decision-making processes.

Provide consistency and standardization on controls across different displays and systems[7]. The transition between states must provide clear and consistent feedback to keep the user in the loop. By limiting the data to simple forms, like alphanumerical values[15], the controllers meaning is easily comprehendible for the user and limits the need for reflection between the controller's state and actual situation.

The controllers should only need a small mechanical force for operation[15], and haptic feedback should be provided from interactions where such data is available. The feedback becomes extra important for touch interfaces. Even though they can have clear visuals, they have no physical changes that the human body can relate to.

Representing Uncertainty

A person's degree of confidence in information can be just as important to decision making as the actual information itself.

Identify missing information

The system must actively identify and inform about missing information. When a detected ship suddenly goes missing or information about it becomes unavailable, it is important that the design presents this in a way that enables the operator to take action. Such features will be important for every aspect of the information provided from the system. This keeps the operator up to speed with the system and aware of which challenges the system is facing so that he can be confident in the information provided and paint a clear picture of what have been left out. The confidence in the system is also highly dependent on the sensor reliability worked out on the data gathering level through initial readings and through the composite data creation of information from different origins with potential of algorithm error along the way.

Reliability assessment
Keep a low display density but focus on information coherence through Gestalt Principles. Stressed operators tend to weight the information in the center of their visual field[16]. This is why the most important information should be available here when needed. The information is also weighted according to placement in reading order from left to right[17]. Weighing different scenarios against each other is a demanding task for the operator as research shows that people are generally poor at handling probability information, especially under uncertainty[18]. When data-uncertainty is present, this should be visualized in a comprehendible way for the operator so that he can efficiently determine the worst-case scenario of the situation. This should be presented without overwhelming the operator with potential scenarios as the uncertain information can grab attention from more important clear situations.

In many cases the uncertainties presented represent the behavioral aspects of the most likely scenario, but for certain situations, completely different scenarios might be of high importance. An example can be navigational fans (Figure 3) representing ship traffic's natural behavior whilst the worst-case scenario could be a completely different course of action due to factors beyond simple navigational course changes.

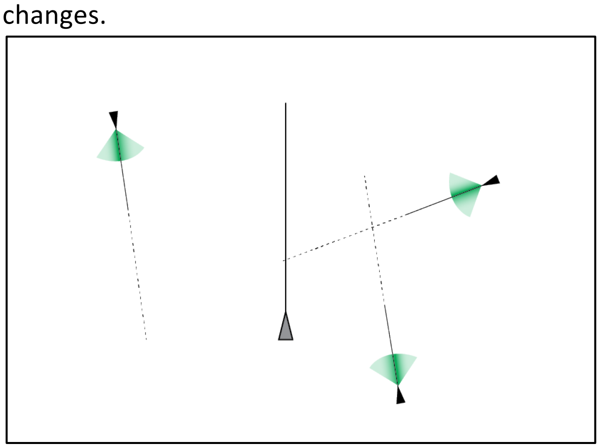

Figure 3: Navigational reliability fans

Use timelines
Active use of timelines will simplify the demand for the brain to make its own sequences of actions and thereby free capacity and smoothen the workflow. This improves decision-making, as the importance of data is clear. The implementation of this concept should go beyond the voyage planning and be utilized for multiple purposes. Timelines can be an effective tool to provide current data accuracy through simplified visualization of update sequences. The use of dynamic shading through luminescent changes can also be an effective timeline-based tool in representing both reliability and importance of information[19] (Figure 4).

Figure 4: Dynamic information shading

Support uncertainty management activities
In order to reflect upon factors of uncertainty relating to the display data, these factors should be presented proximally so that the process of relating them can be executed efficiently. It is important to keep in mind that ship operators have a different level of understanding and that the operator information needs variations depending on routine and cognitive abilities.
There is balance between over presenting calculated likelihood and making room for unanticipated situations that can occur outside the normal patterns. It is highly likely that situations at some point will fall outside the frames created by designers and programmers.

Taming complexity
Multiple screens and integration
Multiple screens demands significant cognitive resources associated with the visual scanning of separate displays and the following mental integration of the information[20]. Integrated screen displays showing radar and ECDIS have proven genuine benefits in terms of supporting normal navigation, possibly with the cost of increased workload and fatigue[21]. With the added features in the shore control ECDIS, there is reason to believe that this would lead to

creeping featurism. This have also been a concern for the maritime community[22].

Seamless operation across modes, functions and interfaces
In order to maintain fluent and seamless operation across different modes, functions and interfaces, there must be a logical consistency in the system. This way the user will gain a better understanding of functions and capabilities, and the disruption created by transitions from one type of action to another will be minimized as the operator is familiar to the interactions, responses and feedbacks.

User-centered hierarchy
Systems tend to be technology centered through logical utilization created from the hierarchy of components and functions. By changing this focus towards a user-centered approach where operational goals and mental models are actively implemented in the design solution, the system can be operated with a significantly increased SA through natural workflows and logic breach minimization. An effective tool towards this goal is grouping information based on level 2 and 3 SA requirements and goals[7].

Transparency and observability
By using a simplifying hierarchy of data presentation, system transparency and observability can be present with varying degree for the different levels of the hierarchy, depending on information needs. Overall performance indicators can be presented at the top level, whilst detailed underlying factors can be accessible at a lower level all the way down to its source components and data.

Alarms
Alarms add stress to the situation. Responding to alarms is a reactive process where mental models and past experienced are playing an active role in determining the underlying problem. When an alarm occurs the operator will most often seek other information to confirm or deny the validity of the alarm. SA has been found to be better and workload lower when alarms include information regarding its validity[23]. Being provided with this information facilitates a rapid and less error prone response.

It is important that alarms add new information rather than adding tasks to situations the operator is currently attempting to deal with[7] to avoid spamming. The alarm should provide enough information for the operator to understand the alarm so that the perceived cues is not falsely interpreted as pieces of a model based on preexisting expectations and incorrect pictures of the situation. People tend to rely on habitual expectations over available data, so this is a dangerous pitfall for prototypical situations.

To support level 3 SA the system should provide trends and developments at an earlier stage so that the operator can take a strategic approach towards the systems direction and act proactive and reassess current states. By visualizing systems in a more comprehendible way, based on their structural relations, the operator can gain a more meaningful understanding of how the system works and reduce the workload of creating a mental picture of the complex system. By also showing the temporal order of alarm occurrence the mental picture becomes clearer.

Repetitive false alarms
Repetitive false alarms can lead to the Cry Wolf Syndrome[7] that results in low confidence in present alarms. This adds an additional consideration process regarding the active alarms to determine their validity. The designer's task is to reduce such instances but in some cases more immediate system changes introduced by the operators might be needed in order to reduce these errors. In such scenarios it is crucial that all operators have an understanding of the changes being made so that they can trust the system a react properly according to its changes.

Faulty alarm trade-offs
A faulty alarm that repeatedly reports false information has a chance of not reporting important new information if switched off. This is why high emphasis should be put into this trade-

off to determine whether to keep the false alarm going or to silence it and stay unaware of further developments.

Consistent multiple modalities
Some instances might need direct commands for the operator to follow whilst other instances will have a dependency on human judgment where additional information is crucial to assist the decision-making process.

Disruptions to ongoing activities
In normal cases the operator will be highly capable of responding to alarms, and alarm confirmation procedures will assure that the operator is present and responding. The problem arises when multiple alarms go off and all of them are requiring the operator to respond simultaneously. Assessing them can be challenging enough itself but the added stress of multiple flashing and sounding alarms can add to a high and undesired level of distraction. There are ways around these challenges as alarms can be set to flash when they are new and stay consistent while they are still important. The flashing can also be periodical to remind when alarms have been unattended for a while.

Global SA in systems alarm state
It is important to keep the overall SA of the system intact during investigation of individual alarms. Digging into specific parts of the system during malfunctions has the potential of distorting the bigger picture. This is why a representation of the system as a whole should be present at any time without any need for scrolling and unnecessary and attended history.

Automation
Automation has the potential of destructing the SA when used for decision-making and option-generating processes. It is important to develop a robust human/ship interface before automation comes into play, as automation should be an aid to the interface rather than a technology-centered system working all on its own. The out-of-the-loop syndrome will occur and have devastating effect if parts of the system, that need more than a glance to gain sufficient understanding, are neglected and suddenly require human decision-making.

Focus automation towards routine tasks
Routine tasks represent a low cognitive demand and an undesired under-load from a human factors point of view[24]. This could be tasks such as correction of course due to minor environmental changes and other parameters, which the automation can safely support, and somewhat perform. They are low on complexity and require a low level of understanding. More demanding parts of the system with a high level of cognitive tasks should however be handled by the operator so that a solid understanding is present in case something goes wrong. This could be an obstacle in the planned route or another ship with critical proximity or collision course. Letting the system create sequences of action on its own creates a narrow operator picture with shortcomings when it comes to the complete SA. However, with operators operating 10 ships and with the chance of communication outage, the ship must be able to handle decision-making if needed.

Support focused SA assistance
Decision assistance has proved to give a higher level of SA than full automation for pilots in planning routes through hazardous areas[25]. By providing support rather than decisions in such situations, the automation can assist rather than handle the critical cases and hence strengthen the SA rather than being an obstacle. This could be distance to a potential complete stop, the turning radiuses provided in the MUNIN ECDIS-view and other valuable information that will strengthen the decision-making process.

Avoid the proliferation of modes
When introducing complex automation systems with several modes, there is a challenge of keeping track of the active modes and how they are operating. This becomes important for a autonomy/ship symbiosis where the tasks are switching between monitoring and different forms of control. Losing control of the active

modes will result in incorrect expectations from the operator side as he expects a different outcome than the current mode can provide. This is why modes should be limited to a minimum and be clearly stated for the operator to enhance usability and error reduction during operation.

Automation consistency
The terminology and symbol usage across automation systems should like all other systems be uniform so that all automation aspects can be understood on the same terms.

Advanced queuing of tasks
Operations that maintain the operators involvement are preferable in order to keep the overall SA up. Advanced queuing of tasks might seem to be the most efficient approach for handling a fleet of ships as the operator can prepare patterns for future events, but the risk of falling out of the loop is severe when the continuous involvement is limited. A way of combating this challenge in navigation is to eliminate long-term plotting of waypoints by forcing the operator to make the navigational changes when needed. This is a minor addition to the operator's workload that adds a significant amount of operator SA.

Information cueing
Automatic cueing of critical information should be used with caution, as important information is likely to be missed if the system cue is wrong. This can be advanced correlation, invisible to the system, between factors that are harmless on their own.

Decision support that create human/system symbiosis
There are several ways of creating an enhanced symbiosis that accelerates the human/machine synergy. Three alternative approaches are[7]: 1) Supporting "what-if" analysis, encouraging people to consider multiple possibilities and performing contingency planning that can help people formulate Level 3 SA. 2) Systems that help people consider alternative interpretations of data, helping to avoid representational errors. 3) Systems that directly support SA through calculations of Level 2 SA requirements and Level 3 SA projections.

Automation transparency
The system should provide visibility into the current and future behavior of automation so that the operator has a clear understanding of the actual situation. Research in aviation has proven this as a tool that results in a significantly lower risk of errors induced by misinterpretation of the data[26]. Given the possibility to observe which task and goals the automation is working towards, the operator can interfere and correct at an early stage. This transparency might seem obvious but current systems tend to lack this aspect, leaving the operator out of the loop, wondering what is going on and why the automation is acting the way it is.

Multi-operator Design
"Creating information from data is complicated by the fact that, like beauty, what is truly "information" is largely in the eyes of the beholder."[9]

A common picture
Individual operators have individual ways of processing information along with varying goals and SA needs, especially on the higher level SA. This is why the use of the control station will differ slightly across teams and locations. It is therefore important to map out the common relevant information to create a solid common picture for the operators.

Display overload in shared displays
When sharing information across displays it is important to share a highly simplified picture with only the necessary information as each team member will have different data needs and therefore will be prone to performance depressing distraction in time-critical tasks. Sharing cloned screens will work against it purpose.

Standardization of information
Even though the information might be displayed in a slightly different way for individual operators, it is important to keep standardized color codes and symbols across the different control stations as significant misunderstandings can occur if co-operators work with different pictures of the same situation. This is a problem that is often induced by insecure programmers that lets the end-user decide upon the palettes of colors and symbols.

Make status of elements and states overt
If monitors have been turned off or if something that typically is shown has been hidden, this needs to be clearly indicated so that other operators will not miss the important information. Status of tasks should be visible to all involved operators so that they are up to speed to the development and have a clear picture of the direction the situation is heading.

Through these design guidelines for team operation, the most important design flaws in multi-operator design can be avoided and lead to the needed additional consideration necessary for creating high levels of shared SA in teams.

5. DISCUSSION

The human element is vital in the introduction of this futuristic and visionary approach to one of the ground pillars in our global society. Proving that the humans are still in control of the autonomous vessels operating alongside traditional seafarers is essential to gain acceptance for what parts of society sees as science-fiction. The guidelines described in this article are creating a framework for developing the enhancing human/autonomy symbiosis needed to create a new reality with better terms for workers, society and environment. By applying the guidelines to actual prototypes, the concept can get one step closer to the goal of enabling unmanned operation in international waters. This might not happen at first, but the framework can be implemented in a smaller scale through hybrid solutions to prove their validity towards the initial purpose of changing the way society sees the future of commercial shipping. The challenges regarding bandwidth and system stability will improve as technology keeps evolving. As similar solutions are more or less operative on both land and in aerospace, it is fair to assume that the industry as a whole will be heading in the direction of autonomous vessels at some point in the future. It might start of as a shore assisted, downsized crew, or a limited number of vessels per operator as the system require a different set of skills with a new approach to navigation. It might even be implemented as a pure simulation to prove that sufficient Situation Awareness can be achieved, but in time, and with further trust in modern technology, the concept is viable from a Situation Awareness point of view.

6. CONCLUSION

The guidelines presented in this article are created using Situation Awareness principles and human limitations combined with a defined concept of shore-based operation of unmanned autonomous vessels created by the industry. The guidelines create a framework for designing an enhanced human/autonomy symbiosis with the potential of creating a safer and less cognitive demanding system, which possibly represents a more viable and accepted solution to the introduction of ship autonomy.

7. FURTHER DEVELOPMENT

Further development of the guidelines should be done by creating a user interface concept, based on the presented framework, in order to validate the guidelines' potential towards their goal.

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