Overview maintenance in man-machine environments: applications in ship navigation

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1. SETTING THE SCENE: KEEPING WATCH ON A SHIP’S BRIDGE

Overview maintenance is important in many different kinds of man-machine environments because operators in these environments have to monitor and synthesise information from many different sources in order to know what is going on. Each of these environments has particular characteristics that influence the ability of an operator to maintain overview. These characteristics consist of the a) working environment itself and b) the tasks an operator has to perform within this environment.

This dissertation focuses on keeping watch on a ship’s bridge as an example of performance in a man-machine environment in which overview maintenance is important. Although the ship’s bridge and the main task of operators on a ship’s bridge may show similarities with more often discussed performance in a cockpit, there are a number of unique characteristics. As a general introduction, this chapter outlines these characteristics of keeping watch on a ship’s bridge for two reasons: 1) to familiarise the nautical layman somewhat with keeping watch on board ships, and 2) to indicate potential hazards for overview loss during watch keeping on a ship’s bridge.

1.1. THE WORKING ENVIRONMENT OF THE WATCH KEEPER

In order to discuss the tasks of the watch keeper and understand which characteristics may contribute to loss of overview, we need to have some knowledge of the working environment of the watch keeper. This working environment can be divided into a) the hardware of the watch keeping environment, that is the ship’s bridge, and b) the equipment on the bridge that contributes to how watch keepers perform their tasks and maintain overview.

1.1.1. The ship’s bridge

The bridge is the highest part of a ship, from where one has the best overview of both the body of the ship and the sailing area. On some ships, particularly naval vessels, the bridge may be the only place where one can look outside. To give as wide a view as possible, most bridges have windows on all sides. Because of equipment placement, in some ships 360 degrees of sight is only indirectly available by means of bridge wings, which are balconies on either side of the bridge. The position and views afforded by the bridge, make it the best place for keeping watch and maintain overview.

1.1.2. Watch keeping equipment

First of all, the bridge contains a helm and propulsion controls to navigate the ship. To collect information that is relevant for keeping watch, the bridge contains equipment that includes both traditional and modern devices. The most important traditional devices are: a chart table and plotting aids, compasses, and binoculars. Modern devices include: radar with an electronic plotting aid (ARPA), global positioning system (GPS), and automatic indicators for wind, current, speed, headings, rudder direction, and under keel clearance (UKC). The bridge also contains many communication devices, used to receive messages and contact other vessels and traffic services (VHF, telephone, NavTex (a kind of fax) and signalling devices).
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On the one hand, watch keepers can use these visual and auditory devices actively to solve problems or get particular information. On the other hand, watch keepers also have to monitor them frequently when problems are absent since these devices may be potential sources of important information the operator is not actively looking for. Whatever the reasons for collecting information with help of these devices, the watch keeper has to integrate the information in order to know exactly what is going on around him. Some modern ships already contain advanced technology to help information integration, such as radar screens with an electronic projection of the chart of the sailing area (Ecdis).

Although traditional navigation methods are used when automation fails, modern equipment has taken over many of the traditional tasks of the watch keeper. The increasing automation has made the watch keeper more and more a system controller within the specific situation of the ship’s bridge.

1.2. THE TASKS OF THE WATCH KEEPER

According to the 1VVKM2 (Regulation of the Royal Netherlands Navy, article 3600), the main tasks of the watch officer consist of a) navigation, b) seamanship and c) meteorology. On a cognitive level, these tasks and their components may however be rearranged into two main tasks: 1) navigation and 2) guarantee of safety. Besides those two tasks, the watch officer has some additional responsibilities that may be termed general interactions. All these tasks will be discussed in the next section. Their contents are based on the relevant parts of the 1VVKM2, but with some additional remarks, and reorganised into a cognitive framework (Table 1).

1.2.1. Navigation

The first main task of a watch keeper on a ship’s bridge is to navigate the ship from a starting point to a particular destination. This navigation task does not only consist of ‘vehicle manoeuvring’, as is the meaning of ‘navigation’ in a narrow sense, but also consists of a number of additional subtasks. Before a journey starts, the watch officer has to plan and prepare the ship’s route in order to know in what direction the ship is going to sail. This preparation includes collection of relevant hydrographical and meteorological details the watch officer has to reckon with during the journey. All this information determines the route the watch officer has to follow and the speed the ship has to maintain. A good preparation is important since, opposite to car driving, travelling routes are more free, and boundaries of safe sailing areas are not always clearly visible. Furthermore, the mass trough which ships sail is not solid and changes continuously, which may account for misleading information. For these reasons, watch officers need to check the position of the ship by applying the available navigation devices. If there is a difference between the collected and expected information, the watch officer has to find out what is going on, and eventually correct his position.
### Table 1: Hierarchical task representation of the tasks of the watch keeper on a ship’s bridge.

#### 0. Keeping watch

1. **Navigation**
   - 1.1. Journey preparation
     - 1.1.1. Collection of information beforehand
     - 1.1.2. Combining information
     - 1.1.3. Adaptation of plans
   - 1.2. Maintenance of route and speed
     - 1.2.1. Checking position
     - 1.2.2. Double-checking with other methods
     - 1.2.3. Keeping a logbook

2. **Guarantee of safety**
   - 2.1. Remaining alert for unexpected events
     - 2.1.1. Keeping a good lookout
     - 2.1.2. Anticipation of dangerous situations
   - 2.2. Collection of relevant information
     - 2.2.1. Collection and interpretation of meteorological information
     - 2.2.2. Dealing with other traffic and obstacles in the environment
   - 2.3. Application of appropriate measures
     - 2.3.1. Taking measures to handle unavoidable situations
     - 2.3.2. Complying with the rules to prevent dangerous situations

3. **General interaction**
   - 3.1. Situation dependent allocation of tasks
   - 3.2. Information exchange
     - 3.2.1. Information exchange to internal parties (technical support)
     - 3.2.2. Information reports to the captain
     - 3.2.3. Information exchange to external parties
     - 3.1.1. Assessment of situation and urgency of tasks
     - 3.1.2. Allocate tasks to right people
     - 3.1.3. Manage bridge personnel
     - 3.1.4. Communicate decisions
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1.2.1.1. Journey preparation

Planning a journey starts with determining the destination of the ship. The destination consists of information about position and time. This time and position information forms the basis for the hydrographical and meteorological information the watch officer has to collect because they influence the route the ship can sail. Planning a journey is not simply an accumulation of all the information the watch officer can get beforehand, but involves combining information to make optimal navigation decisions. Navigation decisions can be determined by the handling quality of the ship in combination with the environmental characteristics. For example, big vessels cannot sail in shallow water because of a phenomenon called ‘squat’: high speed pushes the vessel deeper into the water and may cause it to ground.

Other factors that influence planning are emotional, social, and economic factors. Long periods away from home, living in a confined situation, and increasing sleep deprivation may take their toll. Social and emotional well-being may be very important factors in these circumstances to prevent unsafe actions and to optimise performance. Economic factors are particularly important for the merchant navy and may influence decision making to prefer the most economic over the safest route.

Since information changes with time, a watch officer has to plan before and during his shift, anticipating future events. Well-prepared journeys have the positive effect of lowering mental workload and increasing the level of confidence of the watch officer. There will be fewer unexpected encounters, and more time available to review the current situation and eventually adjust plans. This may facilitate maintenance of overview, especially when problems arise. When a watch officer does not know what to expect, a poor overview may increase the danger of bad decisions.

1.2.1.2. Maintenance of route and speed

To stand by agreements with external parties, the watch officer has to follow the charted voyage as closely as possible, and maintain speed. Successful execution of these tasks has the advantage that the watch officer does not need to adjust plans, saving additional work, which reduces the risk of overload. Overload may lead to a poor overview, since too little time is available to monitor and integrate all relevant information in the environment. This may cause the watch officer ‘running after the facts’, which may result in dangerous situations.

To verify the ship’s position, the watch officer has to check location information by means of the available navigation equipment. Position checking is important for ship navigation because safe routes are not always clearly visible. Several position checking methods exist, but all have advantages and disadvantages. A watch officer can check his position by dead reckoning, which involves frequent estimation of the ship’s actual position based on the expected geographical heading and speed. However, this method is rather inaccurate and is typically used only as a backup when equipment fails. In sight of landmarks, watch officers can check the ship’s position by measuring the relative bearing to clearly visible, and widely different landmarks also located on the chart. The cross-point of these relative bearings represents the approximate position of the ship. Although relative bearing is far more accurate than is dead reckoning, the method is not free of error and is only applicable when the ship is in sight of land. Known landmarks are only useable when they are indicated on the chart, are recognisable, and identifiable. Furthermore, the landmarks must have sharp
contours in order to reduce measurement errors. The most advanced way of estimating position is by means of the **Global Positioning System** (GPS), which receives and combines earth co-ordinates and time signals from orbital satellites to fix the position of the ship. Although the GPS information is usually very accurate, slight errors are possible. These errors can make the final displayed position somewhat inaccurate, but generally, GPS is the most preferred position checking system.

Ideally, the watch officer should use several position checking methods simultaneously to double-check the information to prevent misreading or unawareness of equipment failure, which may result in the ship’s position deviating. Double-checking of information also has the advantage that the watch officer is more certain of his situation overview, and thus reduces the risk of being taken by surprise.

An additional task of the watch officer is the exact and frequent **description of the estimated position** in a logbook. In the event of an accident, investigators can check the ship’s position information to reconstruct what occurred.

### 1.2.2. Guarantee of safety

Most tasks described by the 1VVKM2 as ‘seamanship’ can be grouped under the term ‘guarantee of safety’. First of all, the watch officer has to **remain attentive for unexpected events** by keeping a good lookout. In conjunction with the navigation tasks, the watch officer also has to **collect relevant information** from the environment that may influence the progress and safety of the ship. If he becomes too much preoccupied with one source of information and does not monitor the other information sources in time, his overview of the situation and the safe operation of the ship is endangered. Furthermore, safe operation in an environment with other traffic is only possible when watch officers **take appropriate measures** if safety is endangered. So, apart from knowing what is going on, a watch officer needs also to know how to solve eventual problems and decide which measure is appropriate. This requires that the watch officer does not run after facts, but anticipates on events that may occur in the near future.

#### 1.2.2.1. Remaining attentive for unexpected events

As the word indicates, a ‘watch keeper’ has to remain alert throughout duty. This means that, as well as for navigation, the watch keeper is responsible for keeping a good lookout, and is prepared to cope with unexpected events. A watch officer can ensure maintenance of a good lookout by checking equipment and scanning the environment. In high mental workload situations, the watch officer may delegate the lookout task to other bridge personnel and is then responsible for frequent checks of their alertness.

Both demanding and calm conditions are hazardous for alertness and anticipation for unexpected events. High workload and inadequate delegation of the lookout task may result in the watch officer failing to notice important equipment failures or developing dangers in the environment. Demanding situations can **attract the attention** of the bridge personnel to the extent that less salient events may be **neglected**, especially because the bridge is too large to make all information available at a glance. Over a longer period, these neglected events may increase the situation demands on the part of the watch officer because he has lost overview.
1. Keeping watch on a ship’s bridge

Calm conditions are hazardous for other reasons. Boredom and lack of external stimulation lead the watch officer to become inattentive and drowsy, with dramatic consequences for his ability to notice unexpected events. Good methods for preventing inattentiveness is to post several people on the bridge, such as a helmsman or additional lookouts, or to give the watch officer simple addition tasks. During night or early morning shifts, a conversation or a simple task may prevent dozing and thus assist safe operation. Additional tasks may however only succeed in improving alertness if they do not occupy the watch keeper too much.

1.2.2.2. Collection of relevant information

Besides maintaining alertness, the watch officer also has to collect information actively from the environment. This task consists particularly of monitoring changes in weather conditions, near-future encounters, and objects in the direct environment of the ship. If the weather is about to worsen, maintaining route and speed may become lower priorities. Since big storms on the open sea can capsize even huge vessels, sailing via a safer route is often preferred. Avoidance of storm encounters is however not always possible. The only way to cope with such situations is to turn the ship into the wind and remain in this position until the storm is over. Other weather-changes that the watch officer must monitor are a decrease of visibility due to bad weather. By collecting weather information, the watch officer can anticipate important changes in the situation of the ship and prepare alternative plans to deal with this situation.

Other environmental information that may be important includes traffic that follows a collision course or objects, such as oil-platforms or buoys, in the vicinity of the ship. Although the space per vessel on open sea may be very large in comparison to cars on a road, ships are often difficult to manoeuvre. As a consequence, appropriate actions need to be initiated at an early stage.

In sum, the watch officer has to collect dynamic information from the environment, which is unpredictable, and which can form a potential danger to the ship and its crew. Early collection of this information anticipates events and minimises the need to 'run after the facts' and lose overview.

1.2.2.3. Application of appropriate measures

Although collection of information from the environment may result in a good overview of the situation, this is no guarantee for safety if the watch officer does not react appropriately. In the case of weather changes, for instance, the watch officer may adapt his speed and prepare the crew of the ship for additional tasks, such as anchorage and signalling. When other vessels are on a collision course, the watch officer may contact them or adjust his route.

The watch officer has to apply appropriate measures in cases where danger is approaching the ship. By complying with the rules, the watch officer can partially prevent the development of dangerous situations. Rule compliance saves a large amount of effort in making appointments with other traffic and in coping with ambiguous situations. This prevents too high mental workload and loss of overview. By following the rules, the watch officer clearly shows that he understands the situation, which enhances safe navigation and interaction with other traffic. Rules also have the advantage that behaviour of other traffic can more easily be
understood and extrapolated to the most likely movements in the near future. This reduces the number of possible actions the watch officer has to reckon with, which reduces mental workload and the danger of overview loss. Expectations about rule compliance of other traffic may however also become hazardous if, once in a time, such expectations are wrong and the watch officer fails to monitor the situation in time.

1.2.3. General interaction

Apart from navigation and guarantee of safety, the watch officer has other responsibilities that may be termed 'general interaction'. General interaction consists of two main tasks: first the delegation of tasks to others when the watch officer is unable to manage them by himself. It is important that the watch officer monitors the situation critically and decides in time that he needs others to help him managing the situation to prevent the mental workload becoming too high. This may endanger his situation overview. Secondly, the watch officer is the pivot for information exchanging, receiving input from the crew about the ship, and giving information to the captain in case of important changes. Furthermore, he is responsible for appropriate communication with the outside world. Communication is important to provide clarity about intentions of the parties involved. This may prevent the development of ambiguous situations and misunderstandings.

1.2.3.1. Situation dependent allocation of tasks

Different situations require different tasks to be performed, determining in large part the mental workload of the ship’s crew. During calm conditions, the watch officer can easily manage his tasks solo, although a helmsman may remain available to perform rudder adjustments and double-check actions. In demanding conditions, such as harbour approaches, navigation in confined waters, sailing in areas of dense shipping traffic, or emergencies, there is often more information than one or two persons can manage. In this case, the watch officer is responsible for delegation of tasks to other crew members to prevent mental workload to increase so much that errors may occur and the watch officers loses his situation overview. If the watch officer decides to delegate tasks, he must first make an assessment of the situation and the urgency of particular tasks. Then, he must allocate the tasks to qualified and available crew members. Even the captain may come to the bridge to assist the watch officer to make the best decisions. It is important that the watch officer delegates tasks at an early stage of a demanding situation, to prevent that reorganisation of tasks on the bridge increases the situational demands on the watch officer even more with the result of overview loss.

If the watch officer has delegated most of his tasks, his role is to manage the crew on the bridge, and combine the information they provide, in order to maintain overview and eventually make decisions. If he decides that an action should be taken, the watch officer communicates this to the right person. Although the captain is the main person responsible for the ship, the watch officer functions as the captain delegate concerning everything that has to do with the movements of the ship. Therefore, the main base of good watch officer performance is maintenance of overview.
1. Keeping watch on a ship’s bridge

1.2.3.2. Information exchange

Besides being the main place for navigation, the bridge also forms the central information point, with the watch officer as manager of this information. The information consists of an internal and an external flow. The internal flow concerns information exchange within the ship’s crew. One of the sources inside the ship that is in close communication with the bridge, is the machine centre. Personnel in the machine centre will inform the watch officer when he has to reckon with technical limitations. These can handicap the manoeuvrability of the ship. The watch officer informs the machine centre when planned manoeuvres may have negative results for the engines, or when he suspects improper system functioning. Timely repair of system problems is indispensable since an immanoeuvrable ship is dangerous for both the ship and other vessels. Correct exchange of information can prevent this, or can at least make that the watch officer reckons with incidental limitations of the ship.

In naval vessels, another important information source is the command and control centre, in which other ship officers watch a backup radar-screen and warn the watch officer on the bridge about possible undetected contacts. During wartime operations, the operations officer also provides tactical information that may influence the decisions of the watch officer.

Another important internal information flow concerns the information exchange with the captain. Although the watch officer is the first responsible person for actions taken, the captain has the final responsibility and therefore, the watch officer is obliged to report all important information to the captain. This information may concern deviations from planning or difficult situations requiring extraordinary actions. The captain, in his turn, may ask spontaneously for situation information (situation report or SitRep). This practice keeps the watch officer alert. Such a chain of command motivates the watch officer to perform well and enables him to maintain a good overview.

The external flow of information concerns communication with the external world such as other shipping traffic and port authorities. This includes the exchange of emergency calls as well as appointments to resolve any ambiguity. Although this flow of communication can be very crucial for the operator’s anticipation of near future events, such exchanges contribute to the continuous flow of mostly irrelevant background noise on VHF in stand-by mode, originating from information exchange between other shipping traffic. A watch officer has however to remain alert for information that may be important for him.

1.3. Situations that may provoke loss of overview on the bridge

In conclusion, watch keepers on a ship’s bridge may encounter many different situations that may result in loss of overview of the large amount of information they have to monitor. Although little research has been performed in revealing knowledge of particular situations on a ship’s bridge that may endanger guarantee of safety, a number of factors are supposed to contribute to hazards. Situations that put high mental workload on the part of the watch officer may, in general, increase the risk of human errors. More in particular in relation to maintenance of overview, ambiguous or complex situations may easily result in the watch keeper to lose overview. These factors will, among others, be investigated in this dissertation.