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# SITUATION AWARENESS IN TRAFFIC MANAGEMENT CONTROL ROOMS

## THE IMPORTANCE OF TRAFFIC MANAGEMENT SYSTEMS INTERFACE DESIGN

# 1. THE ROLE OF SITUATION AWARENESS

Operators in traffic management centres are responsible for a safe and efficient handling of traffic flows. In traffic management centres, operators nowadays deal with many different information systems. They need to integrate the information from these separate systems into one reasoning model themselves. Several trends within Dutch traffic management however endanger the effectiveness of traffic control (Rijkswaterstaat 2011), (Rijkswaterstaat 2012a), (Rijkswaterstaat 2012b):

- Increase in quantity of traffic
- Increase in complexity of traffic
- Increase in controlled objects and areas
- Corridor management and regional cooperation instead of local traffic management
- Growth in amount of data, applications and operating systems used
- Focus on personnel reduction

Above trends result in an increasing amount and complexity of information needed by operators for traffic management tasks. This increased amount of information presented on separate information system interfaces makes it too difficult for operators to generate a sufficiently clear mental picture of the traffic situation, resulting in a lack of situation awareness.

Endsley (1995) proposed a situation awareness theory that has been transformed into several models, among which is by far the most commonly used model of situation awareness (Endsley 1995), (Salmon et al. 2006), (Wickens 2008), (Dao et al. 2009), (Feng et al. 2009). In this model situation awareness is defined as *"the 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"*. The above model identifies three levels of situation awareness:

**Level 1:** The perception of the status, attributes and dynamics of relevant elements in the current situation.

**Level 2:** Comprehension of the current situation, based on synthesis of disjointed level 1 elements.

**Level 3:** Projection of future actions of the elements in the environment, through knowledge of the status and dynamics of the elements and comprehension of the situation.

The process of acquiring and maintaining situation awareness is considered to be influenced by: (i) the operator's individual characteristics and conditions, (ii) the aspects related to the task at hand and (iii) the characteristics of the systems used for task execution, see Endley's model in Figure 1. In the next section, we will discuss the factors that according to Endley's model influence situation awareness in Dutch traffic management practice.

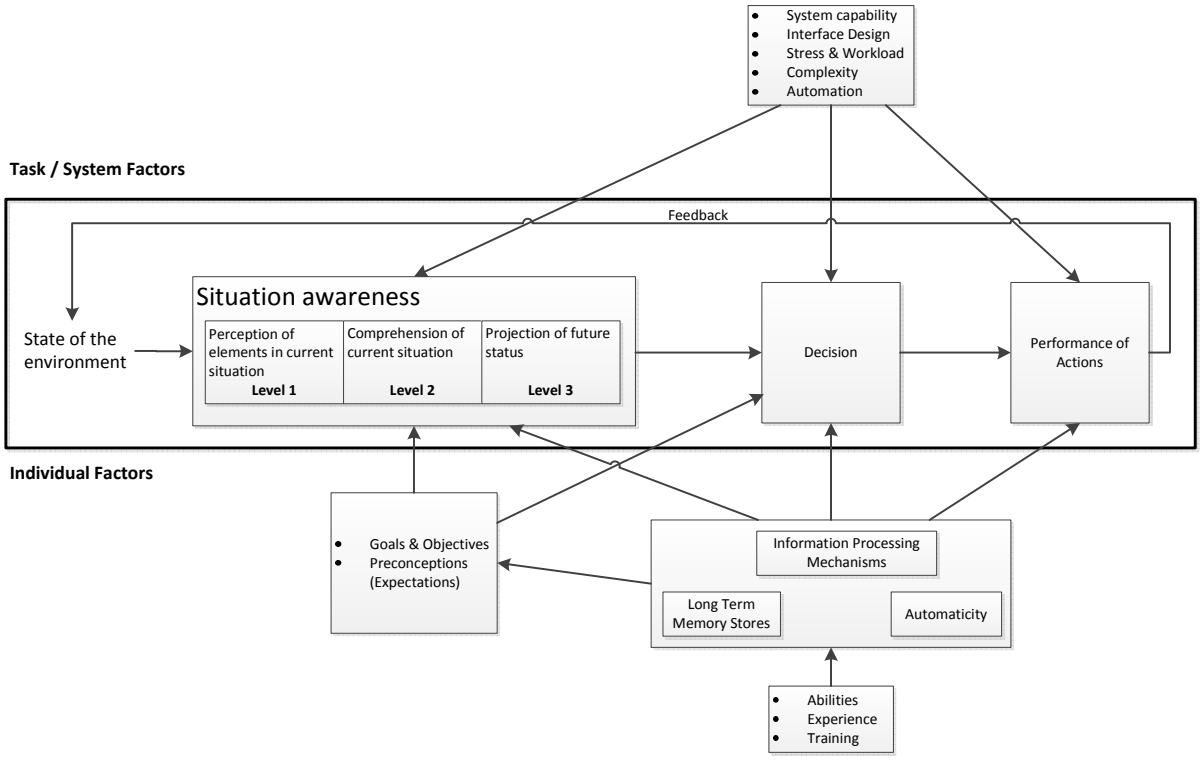


*Figure 1: Endsley's model of situation awareness in dynamic decision making (Endsley 1995)*

## 1.1 INDIVIDUAL FACTORS

Individuals vary in their innate information processing ability to acquire situation awareness. This ability can be influenced by experience and training. Personnel selection and training for traffic management tasks acknowledge the importance of situation awareness skills (IALA 2009). Thus, only those individuals with sufficient abilities in information processing for situation awareness are selected and are able to fulfil the mandatory educational program.

Besides abilities in information processing, operators' goals, objectives and preconceptions influence the situation awareness process. Within the Dutch traffic management centres, uniform working methods with clear goals and objectives are used to support operators in acquiring the required level of situation awareness for the task at hand.

### 1.1.1 Information processing

Landry, figure 3.

## 1.2 TASK FACTORS

There are several task-related factors that influence the operators' ability to acquire situation awareness. Stress, workload and complexity are considered to be the main task factors which influence this ability.

### 1.2.1 Stress

Stress factors that may influence the operator's ability to acquire situation awareness are both physical stressors, like noise, lightning, temperature and atmospheric conditions and social psychological stressors (Endsley 1995). Physical stressors are taken into consideration when designing control rooms and workplaces, demanding comfortable work environments (Comité Européen de Normalisation 2005). Psychological stressors, like personal problems or consequences of work-related incidents, are less easy to control. Within Dutch traffic management centres, both operators themselves as the daily supervisors are responsible for recognizing and acting upon psychological stressors, with a possibility to relieve or even temporarily replace a stressed operator.

### 2.2.2 Workload

Within traffic management control rooms, workload mainly consists of cognitive task load. Cognitive task load is a function of the percentage time occupied, the level of information processing and the number of task-set switches (Neerincx 2003). Problems of situation awareness can be brought on by cognitive overload, under-load or vigilance problems. Situation awareness and workload however can vary independently (Endsley 1993). While workload problems can have a negative effect on situation awareness, it does not mean that an operator will have sufficient situation awareness when there are no workload problems. And only when workload demands needed for acquiring and maintaining the required situation awareness exceed maximum human capacity, is situation awareness necessarily at risk. If the overall cognitive task demand is too high, this can result in sufficient situation awareness, but problems in decision making or action performance.

The different aspects of cognitive task load can be influenced by individual factors, task design and support system design. Firstly, selection and training of operators is used to match the workload with the abilities of the operators. Secondly, within traffic management, the traffic management area under control of one operator can be increased or decreased in order to increase or decrease the volume of information and tasks. Since governments strive for cost reduction and thus personnel reduction, an attractive method besides influencing individual and task factors is to optimize support system design. The relationship between situation awareness and workload means that a particular interface design may improve (or

diminish) situation awareness, yet workload may remain stable. With other designs, it may be that operators are able to maintain the same level of situation awareness, yet may have to work less hard (Endsley 2000). If an interface presents information in a manner which is easy to process, high situation awareness can be achieved under conditions of low workload (Endsley 1993).

### 3.2.3 Complexity

The complexity of the operator's tasks may increase through the number of goals, tasks, decisions, cooperation's, a larger span of control, etc. Within traffic management, an increasing amount and complexity of traffic, areas and objects in combination with a focus on personnel reduction and shift from local traffic management to corridor management results in more complex tasks.

Task complexity is closely related to system complexity, like increase in the amount of information presented, number of systems used, the degree of interaction between these systems, etc. (Endsley 1995). Within traffic management, more task complexity resulted in growth in amount of data, applications and operating systems used. Since it is not thinkable to reduce the amount or complexity of traffic and since corridor management is needed to accommodate the increasing amount of traffic on existing Dutch waterways, reducing the system complexity is proposed. Besides, Rijkswaterstaat attempts to reduce task complexity by investigating the effect of introducing new traffic management roles. VTS operators and operators of bridges and locks will perform their primary tasks, while all secondary tasks not strictly related to VTS or operation of bridges and locks will shift towards other traffic management roles.

## 1.3 SYSTEM FACTORS

Endsley's model recognizes different levels to which the system design influences situation awareness; (i) the degree to which the system acquires all the needed information from the environment (completeness of data), (ii) the degree to which the system displays all the relevant information to the operator and (iii) the degree to which the operator is able to process all the relevant information, taking into consideration perception, attention and working memory constraints (Endsley 1995).

In traffic management centres, operators are not able to directly perceive relevant information from the traffic management environment. Environment data is collected and displayed in a remote traffic management centre. This data represents the real situation. The quality of the data influences the operator's ability to achieve situation awareness. Literature

suggests this data shall be complete, secure, reliable, correct and relevant (Endsley 1995), (Essendorfer et al. 2009), see Figure 3. Besides the quality of the data, also the presentation of data influences situation awareness. Data has to be presented in time and in the right place (Endsley 1995).

# 2. IMPORTANCE OF INTERFACE DESIGN

Different trends result in an increasing amount and complexity of information needed by operators for traffic management tasks. The resulting lack of situation awareness is the effect of a combination of the described individual factors, task factors and system factors. Whether an operator has a lack of situation awareness firstly depends on the tasks at hand. While an object planner mainly needs to be aware of the relative position of ships in relation to nautical objects like bridges and locks, a Vessel Traffic Service operator needs a very detailed situation awareness of status, attributes and dynamics of all ships and environmental aspects in his area. If a Vessel Traffic Service operator can primarily recall the relative positions of ships in relation to nautical objects, he has a lack of situation awareness, while an object planner with the same level of situation awareness can have the required situation awareness. The very nature of current traffic management tasks cannot be changed without causing significant traffic problems in the real world if the amount of operators is not significantly increased. Within the current financial climate, increasing the amount of operators is not an option either. In current Dutch traffic management centres, task and individual factors of situation awareness are already optimized through personnel selection, training and work methods and conditions. It therefore is not expected that operators' situation awareness can still be significantly improved by focusing on the deficiencies of current task design and individual factors, without firstly improving the systems used to achieve situation awareness. With improved systems, task design and training can be adapted to further optimize situation awareness.

The way in which attention is directed across available information is critical to achieving situation awareness, especially in dynamic and complex systems in which there is a risk of attention overload. For information intensive situations, literature suggests automatic integration of information and information processing to positively affect situation awareness (Endsley 1995), (Endsley 2001), (Goossens et al. 2004), (Essendorfer et al. 2009), (Gupta and Mukherjee 2009). Several projects within Rijkswaterstaat aimed to improve operator's support by introducing a man-machine interface which is not constructed from loose information systems, but that combines the information from several underlying information systems into one coherent informing interface (Rijkswaterstaat 2008), (Rijkswaterstaat 2011), (Rijkswaterstaat 2012a), (Rijkswaterstaat 2012b). Summarizing suggestions by literature and practice, we can extend Endsley's model of situation awareness, see Figure 3

and 4. In the next section, we will discuss the different suggestions to optimize situation awareness support, summarized as implementing a holistically informing interface.

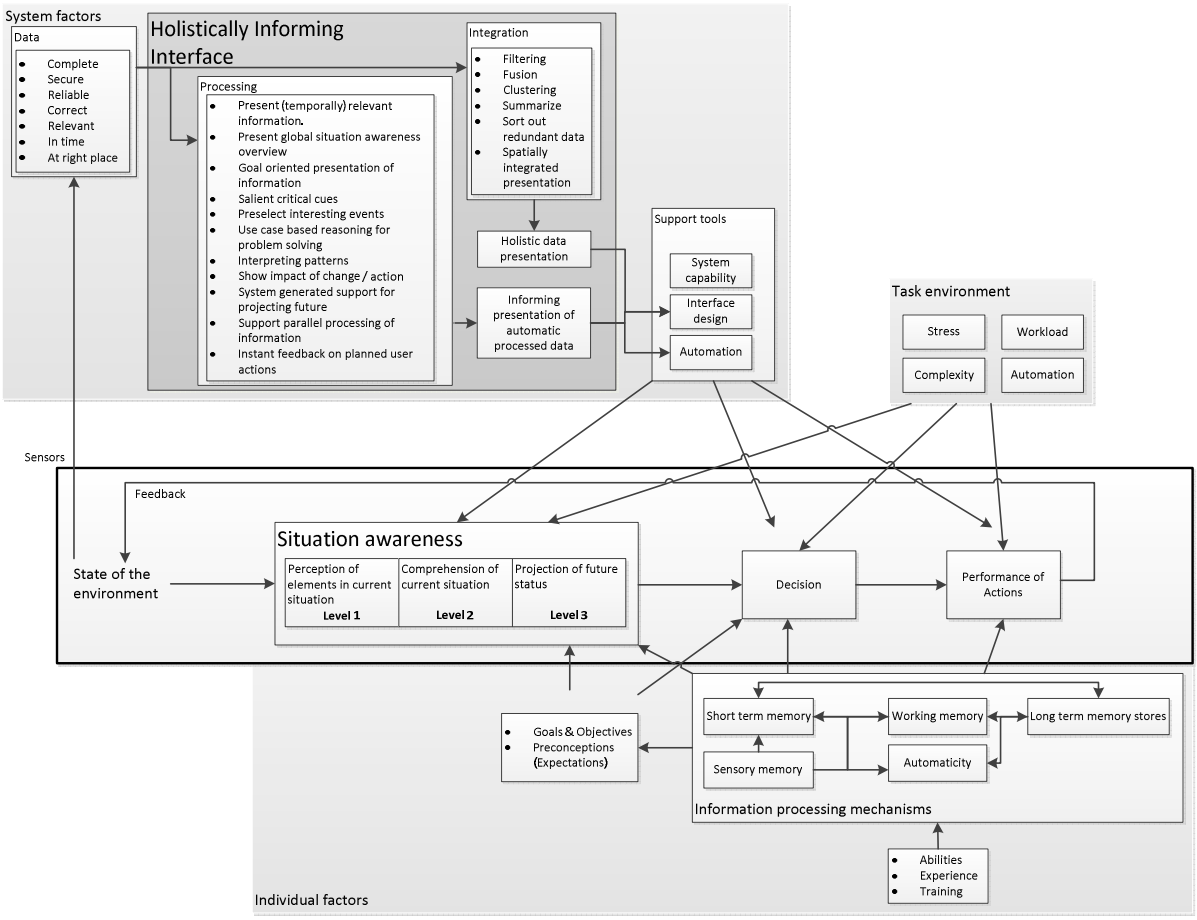


*Figure 2 Current understanding of holistically informing interface aspects influencing situation awareness, from literature review (Endsley 1995), (Endsley 2001),(Goossens et al. 2004), (Wickens 2008), (Bellet et al. 2009), (Essendorfer et al. 2009), (Gupta and Mukherjee 2009), (Landry 2009)*

## 2.1 TOWARDS A HOLISTICALLY INFORMING INTERFACE

It is our hypothesis that a holistically informing interface better supports situation awareness than separate information interfaces. Figure 4 gives a first insight in holistically informing interface related information availing principles suggested for improving situation awareness.

With separate information system interfaces, several systems present their own set of data. Each system has its own user interface. Information in the separate systems can overlap or conflict. Holistic information interface means that the man machine interface (MMI) is not constructed from loose MMI's of underlying systems, but that the MMI is designed as a coherent whole. This means that information from different underlying information systems is logically integrated, (Endsley 1995), (Endsley 2001), (Goossens et al. 2004), (Essendorfer et al. 2009), (Gupta and Mukherjee 2009), see Figure 4 and 5. The different information sources about a single process or one object are presented in one location. This means that

information from different underlying systems is presented together. An operator no longer needs to merge this information mentally. Overlapping data is presented once. Conflicting data is pointed out. While the separate information interfaces often have their own use of symbols, workflows and interaction elements, within a holistic information interface, there is a uniform man machine interaction.

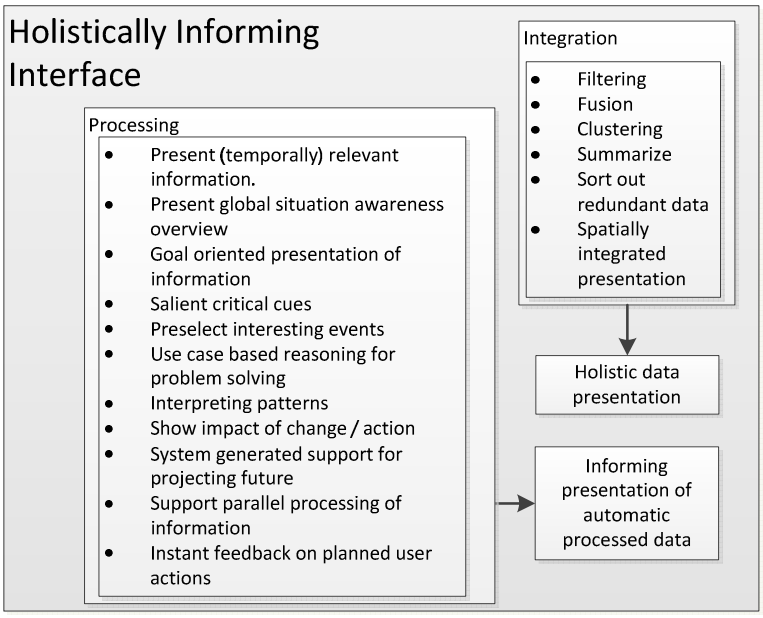


*Figure 3:* Literature suggestions for holistically informing interfaces to improve situation awareness (Endsley 1995, 2001, Goossens *et al.* 2004, Wickens 2008, Essendorfer *et al.* 2009, Gupta and Mukherjee 2009).

An information interface shows available data. When using information interfaces, the operator needs to combine and process the available data mentally. Within the traffic management centre, a huge amount of data is constantly available to the operators. This makes working with information interfaces mentally demanding. An informing interface aims to support situation awareness by adapting the presentation of data to the task at hand by the presentation of processed data (Endsley 1995), (Endsley 2001) ), (Goossens et al. 2004), (Wickens 2008), (Essendorfer et al. 2009), (Gupta and Mukherjee 2009). Within an informing interface, only the information relevant at that moment is presented, see Figure 4 and 5. If relevant to the task, an informing interface can present information is an assimilated visual instead of lists of data.

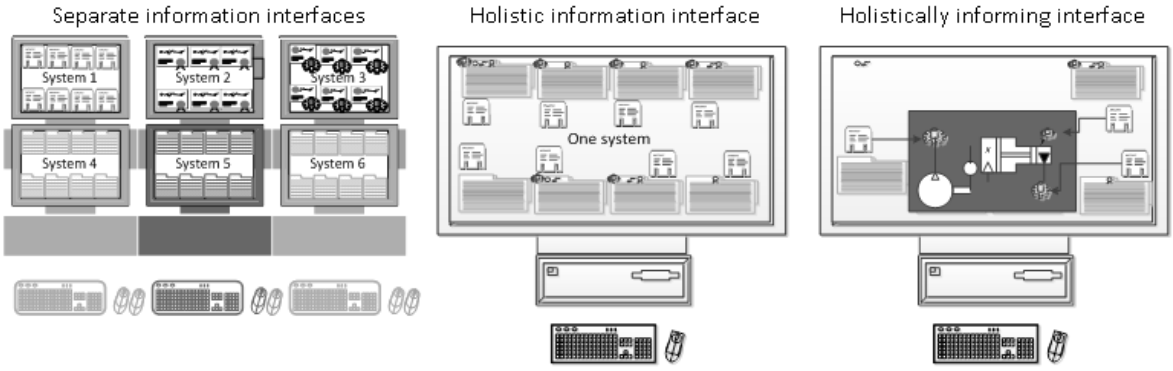


*Figure 4: Separate information systems versus holistically informing interface*

# 3. DISCUSSION

It is generally accepted that situation awareness is needed for traffic management tasks. The deficiencies of current systems, resulting in a lack of situation awareness, are the result of a combination of the described individual factors, task factors and system factors. This paper argued that increasing amount and complexity of information ask for improved interface design of traffic management systems. A new concept of interface design, here called a holistically informing interface, is proposed as potential to better support situation awareness. There however is insufficient knowledge of the deficiencies of current traffic management systems to enable reliable insight in how to overcome the deficiencies of information intensive traffic management system interfaces. The scientific problem at hand includes two interrelated questions:

- What are the deficiencies of current information intensive traffic management system interfaces?
- How to overcome the deficiencies of current information intensive traffic management system interfaces?

Within Dutch nautical traffic management, concrete steps are taken to defend the business case of implementing holistically informing interfaces in nautical traffic management centres. Since there is insufficient knowledge of the deficiencies of current traffic management systems, trial and error and logical thinking were used to develop holistically informing interface concepts. Rijkswaterstaat will use a real-life pilot environment and a more controlled simulator environment to evaluate the generated concepts. This creates an opportunity to study the hypothesis that a holistically informing interface better supports situation awareness than separate information interfaces.

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