EUROPEAN UNION AGENCY FOR RAILWAYS

German Centre for Rail Traffic Research at the Federal Railway Authority

AUTOMATION MYTH #1

Situational Awareness Remains the Same – No Need for Additional Information

Automated Railway - Operation as Usual: Best Practice to Achieve Situational Awareness

SUMMARY

This article aims to provide insights into achieving situational awareness as a basis for safe automated railway operations. Automation in rail transport has a significant influence on employees' situational awareness (perception, understanding and anticipation of the situation), which in turn depends on the degree of automation, task characterisation, the design of the human-machine interface and information content. One decisive aspect for safe operation is the human-centred design of the task and workspace with integrated information as well as regular training and knowledge expansion to enable appropriate situational awareness. Good examples already exist in railways, especially for the visualisation of relevant information considering human and organisational factors and addressing automation myth #1.

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INTRO

The degree of automation is increasing in various applications and contexts, also in the rail sector. This can yield a number of benefits, such as increased safety, reliability, capability and efficiency, if automation operates as intended by the human. However, it leads to greater dependencies, which negatively affects the performance when automation fails or reaches its limits (Bainbridge, 1983). Consequently, the following question arises: How can human-automation performance be successfully optimised enabling operation as usual?

Let us first look at an everyday example: robot vacuum cleaners - those little automated helpers that keep the dust off us. It is not uncommon to see pictures of broken robot vacuum cleaners at the bottom of stairs or a brown trail (at best caused by moist soil) following the robot's path through the room. Why did they (human and robot) fail? For an optimal cleaning result, you need to know the limits of your robot. Thus, you can anticipate and create a situation (move furniture, put things away, etc.) in which the robot can operate without problems. If system limits are not considered and the functionality of the robot is trusted too much, poor vacuuming results can occur in the best case. In the worst case, ramming of other objects or destruction of the robot can be the result. It is also useful to know what the robot is doing, what it has already done and what will happen if you simply switch the robot off or move it to another location. These aspects are related to situational awareness, which can be supported by human-machine interfaces, instructions and training, as a basis for successful implementation. In most cases, misuse of vacuum cleaning robots due to poor situational awareness is not safety-critical, but merely annoying and not purposeful. In other contexts, such as rail transport, a lack of situational awareness can endanger human lives.

SITUATIONAL AWARENESS

Situational awareness is a decisive concept in the context of safety-critical domains (Stanton et al., 2001) as it is the basis for good decision-making and performance (Endsley, 1995). Operators need to perceive and process relevant information, understand and anticipate them in order to know what is going on and what is coming next. The model proposed by Endsley (1995) including three levels to characterise situational awareness has been most widely accepted (see Fig.1).

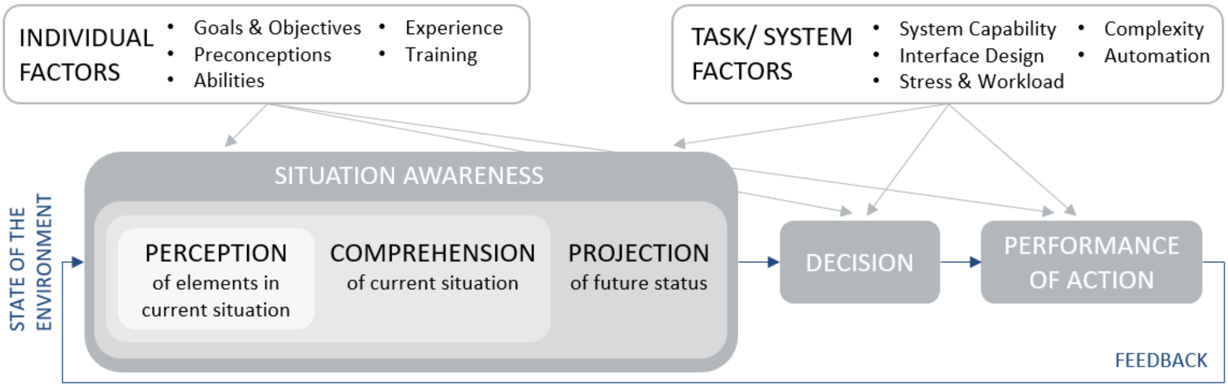

Fig. 1: Three-level model of situation awareness adapted from Endsley (1995)

Individual factors such as experience, preconceptions or goals as well as system factors such as interface design, complexity or automation influence situational awareness (Endsley, 1995). With systems becoming more and more automated and complex, certain system processes are not necessarily recognisable to humans. Operators need be able to understand and predict the situation at any time when they are in control or serve as a fallback solution for automation. Therefore, additional information has to be communicated in a meaningful way and specific automated system knowledge must be reinforced (Endsley, 1996). Experience and frequent use or training also support the development of adequate situational awareness. This is especially the case if the person is rather passive most of the time (observer) and can intervene actively only rarely. Loss of practical knowledge and reduced attention are the consequences, so that important aspects in the situation could be overlooked (Endsley, 1996). In summary, automation thus influences situational awareness in many ways, but if it is very well designed by taking human and organisational factors into account, it can bring a considerable gain in acceptance, safety and physical relief for humans.

LEVEL OF AUTOMATION

Depending on the degree of automation, the range of tasks changes and with it the situational awareness for humans. Automation can be divided into different levels, ranging from manual operation by the human to complete takeover of control without human involvement. There are several frameworks of levels that can have different focuses and scopes. For example, a ten-level subdivision specifically covers control of decision and action selection (Sheridan & Verplank, 1978, see Fig. 2a). These levels can also be defined separately for the different functions of information acquisition, information analysis, decision selection and action implementation related to human information processing when using certain automated systems (Parasuraman et al., 2000).

LEVELS OF AUTOMATION

The system…

LOW (human)

1 … offers no assistance, human must take all decisions/ actions
2 … offers a complete set of decision/action alternatives
3 … narrows the selection down to a few
4 … suggests one alternative
5 … executes that suggestion if the human approves
6 … allows the human a restricted veto time before automatic execution
7 … executes automatically, then necessarily informs the human
8 … informs the human only if asked
9 … informs the human only if it, the computer, decides to
10 … decides everything, acts autonomously, ignores the human

HIGH (system)

a

GRADES OF AUTOMATION

GoA0 On-sight train operation
GoA1 Operation with ATP
GoA2 Operation with ATO & ATP
GoA3 Driverless train operation
GoA4 Unattended train operation

ATO – automatic train operation
ATP – automatic train protection

b

Fig. 2: a) Levels of automation relating to human information processing (Sheridan& Verplank, 1978; Parasuraman et al., 2000) and b) grades of automation (GoA) relating to train operation (Braband, 2021, UITP, 2018).

In railways, the grades of automation (GoA, see Fig. 2b) are commonly used, subdividing levels according to the responsibility of operation for different functions of train operation (Braband, 2021). The combination of both frameworks, broken down to the functional level of train operations, might help to uncover changes in human information processing as GoA levels increase (for an example of integration, see Brandenburger & Jipp, 2017). Human-centred interventions for automated railway operations can be developed on this basis.

ACHIEVING SITUATIONAL AWARENESS IN AUTOMATED RAILWAYS

The concept of situational awareness has already been applied to both manual and automated operations in railways, for instance, for understanding signalling and control in rail operations (e.g., Golightly et al., 2010; Lo et al., 2016; Sharples et al., 2011), train driving (e.g., Brandenburger & Naumann, 2019; Rose et al., 2018) or rail maintenance and trackwork (e.g., Golightly et al., 2013; Tretten et al., 2021). In all these areas of railway, a significant number of automated systems and processes already exist from the perspective of human information processing. For instance, train control systems monitor speed and can (especially at a high level) continuously provide information from the infrastructure, such as monitoring ceiling and target speeds or braking target points. This information is integrated in an optimum manner in the Driver Machine Interface (DMI, see Fig. 3) taking human and organisational factors into account (Metzger & Vorderegger, 2012). It is a standardised interface for the European Train Control System (ETCS) between the driver and the train supporting the development of situational awareness.

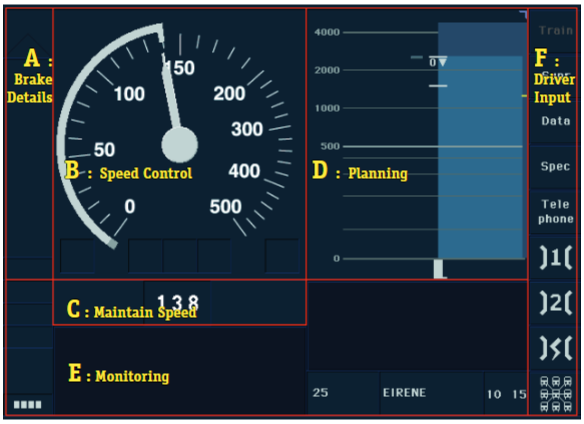

Fig. 3: Integrated Information in DMI (UIC, 1998, p. 5)

What does this mean for the train driver? Compared to the past, the train driver no longer has to initiate the braking process solely based on the fixed signals, kilometre charts, the book timetable (containing slow speed points and the kilometres) and with regard to the train's braking ability. While experience and intuition used to be decisive, the DMI now assists. This interface displays the braking curve and integrates the status information (current speed in relation to the target speed) as well as planning information for speed control and monitoring. If the train driver exceeds the ceiling velocity, a visual and acoustic warning is presented before emergency braking occurs (UIC, 1998). All information is thus integrated and quickly retrievable. Consequently, the DMI supports anticipatory and safe driving. However, this support might lead to a reduction in specific practical and theoretical knowledge of operators, which could be partly corrected with the help of training, e.g. in the simulator.

There are a growing number of examples showing that very high levels of automation are being successfully applied in rail transport (UITP, 2018). For example, driverless or unattended metros (GoA3 or GoA4) operate worldwide in metropolitan areas (e.g., São Paulo, Singapore, Paris, Barcelona, Nuremberg). When monitoring and controlling these metros, a high degree of situational awareness is particularly important in order to detect potential problems at an early stage or, in the event of a malfunction, to assess and resolve the status as quickly as possible. The challenge with driverless or attended operation is that the supervising function is not directly on site, but receives all information via screens in a control centre, thus acoustic and haptic information are missing. However, they also have additional information that is otherwise not available to a driver (e.g. certain camera perspectives or sensor information). Even the role reversal (from driver to observer), the resulting distance from what is happening and the different information change the situational awareness. With the help of the interfaces, it must be ensured that all information is available in the control centre in order to assess the situation correctly and thus act safely and without errors. Furthermore, it is important to point out that functions besides driving and opening doors, such as anticipating, observing, interpreting and reacting to environmental events are handled by regular metro drivers (Karvonen et al., 2011). In an automated metro, these tasks also need to be performed, either through comprehensive monitoring in the control centre or through presence on site. In

Nuremberg, for example, train drivers have been retrained as service personnel who advise and monitor in the stations and intervene quickly on the spot in the event of problems with the automated metro.

CONCLUSION

Automation myth #1 is clearly rebutted by means of selected examples in railways. Increasing automation changes the information needs for the human operator to understand and anticipate the situation and thus decide and act safely. What information is necessary to maintain good situational awareness for 'operation as usual' depends on the level of automation applied to human information processing. The way the information is presented (interface design), how the task is designed and how knowledge and experience are enhanced is also crucial. The key is putting people at the heart and not underestimating the complexity of human and organisational factors that influence performance in a socio-technical system.

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