EUROPEAN UNION AGENCY FOR RAILWAYS

German Centre for Rail Traffic Research at the Federal Railway Authority

AUTOMATION MYTH #4
Automation disenfranchises the human operator, making a teaming between humans and automation impossible

New form of teamwork: Teaming between humans and automation

SUMMARY

Due to technological advances, automation is nowadays no longer regarded only as a tool for humans but, due to the execution of complex tasks, is increasingly discussed in terms of a team member. This article describes how successful teaming can optimally be realized so that the strengths of the human operator and the automation are brought to bear. The decisive factor is a human-centred work design that focuses on the needs of human operators. An example from air traffic control is used and findings are transferred to the handling of existing interlocking technologies in the rail industry. First tendencies of teamwork between signallers and automation are already emerging today. In the future, this new form of teamwork can be further developed with the help of the introduced model on the key aspects for a successful teaming between humans and automation.

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INTRO

I would like to demonstrate the complexity of the interaction between humans and automation in the work context using an example from air traffic control. The job of air traffic controllers consists of supervising and navigating air traffic in an assigned airspace. In order to increase efficiency and safety, automated assistance systems are increasingly being introduced, such as the Arrival Manager. The Arrival Manager provides specific suggestions on the optimal approach sequence to an approaching airport, considering various parameters such as flight path, speed, runway conditions, etc. (Eurocontrol, n. d.; Skybrary, n. d.). It demonstrates to the employees how to optimally navigate in specific situations. However, what was originally seen as a beneficial advance for the industry is now perceived as somehow negative by some employees (cf. Rieth, 2022). They feel disenfranchised by the automation. Their active and creative work of generating a meaningful approach sequence out of the "traffic clutter" has been transferred to the system. If air traffic controllers use this automation, they have to check the approach sequence created by the automation in a time-consuming manner and implement it more or less passively. Within the implementation process of this system, it was not considered that it automates a task which, from the employees' perspective, is the attraction of their job, i.e. a work aspect with which they strongly identify in their job. The holistic effects on the overall system – consisting of automation *and* humans – were not considered comprehensively. As a result, instead of the expected benefits of automation, unintended negative consequences may result in the long term, such as job dissatisfaction, declining motivation and consequently reduced performance.

TRANSFORMATION OF AUTOMATION FROM A TOOL TO A TEAM MEMBER

Today's working world is characterized by the ever-increasing use of automation. In the past, mostly only simple routine tasks could be automated. Today, technological advances in machine learning and artificial intelligence also enable the automation of diverse cognitive, complex tasks (Moray et al., 2000; Parasuraman et al., 2000; Sheridan & Parasuraman, 2005). Such higher degrees of automation are usually come along with automation that not only assists humans in *information acquisition* and *analysis*, but also acts at the stage of *decision selection* or *action implementation* (Parasuraman et al., 2000). For example, automation suggests solutions to humans for the task at hand, gives concrete instructions on how to act, or executes actions automatically. Nowadays, technology can even handle subtasks autonomously, i.e., it can work with little or no human intervention (Demir et al., 2019; Hancock, 2017). As a consequence, automation is no longer seen as a tool, but is increasingly discussed in terms of a team member (Demir et al., 2019; Rieth & Hagemann, 2022).

In the scientific literature, this topic is discussed under the term *Human-Autonomy Teaming* (cf. O'Neill et al., 2022). By definition, a human-autonomy team is composed of at least one person and a (partially) autonomous technical unit, the so-called (partially) autonomous agent. They work together in an interdependent relationship to successfully accomplish a common task (O'Neill et al., 2022). An autonomous agent can adapt to changing requirements and make decisions independently (Demir et al., 2019; Hancock, 2017). Consequently, autonomy goes hand in hand with a higher degree of automation (Hancock, 2017). Technologically, only partial autonomy can be realized in most cases today, especially in safety-critical areas. Here, the technical agent acts autonomously within a pre-defined scope for a very specific subtask (O'Neill et al., 2022). Consequently, humans are still needed, resulting in close collaboration between humans and technology (Endsley, 2017; Wooldridge, 2013) equal to teamwork. Both parties contribute collaboratively and interdependently to an overarching common goal.

HUMAN-CENTRED WORK DESIGN AS THE KEY TO SUCCESSFUL HUMAN-AUTONOMY TEAMING

The introductory example shows that automation can also be perceived negatively by users because it disenfranchises them and interferes with their autonomous decision-making process. Thus, the question arises as to whether a teaming between humans and automation is actually feasible. The key lies in the concrete work design (Gagné et al., 2022; Parker & Grote, 2022). Two different approaches are differentiated here. The *technology-centred approach* focuses on the capability of the technology. All those functions are automated that can be performed more accurately, efficiently, or reliably by a technological system than by humans. The remaining tasks stay with the human in the sense of the left-over principle (Parasuraman & Riley, 1997; Roth et al., 2019). This approach can result in restrictive working conditions for humans, e.g., if they are only assigned passive tasks as a result of automation. Thus, there is an increased risk that humans perceive their work activities as less meaningful, monotonous, and boring, which can lead to inattentiveness, demotivation, and consequently to performance losses (Parker & Grote, 2022). In contrast, a *human-centred approach* focuses on human needs within the context of automation design, implementation, and use (Billings, 1991). Here, automation is used to compensate for human limitations or to enhance human capabilities. The aim of automation is to support humans in the best possible way (Billings, 1991). This approach considers that it is not always reasonable to automate everything that leads to more efficiency. Instead, the effects on humans are taken into account and the costs and benefits are assessed holistically.

With the help of the human-centred approach, human-autonomy teaming can be successfully realized without humans feeling disenfranchised by automation. The following model shows which aspects can be conducive to realizing such teaming (Fig. 1).

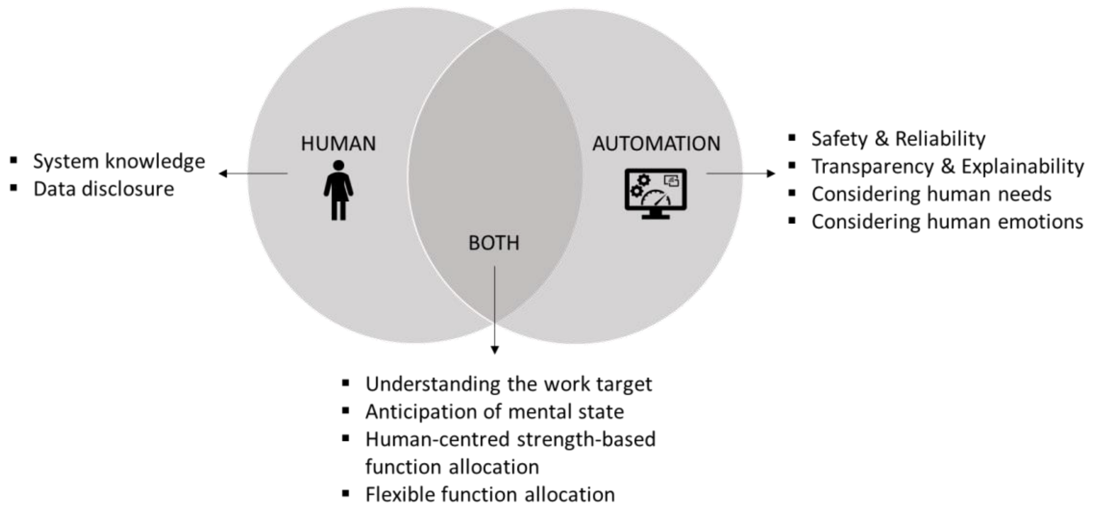

Fig. 1: Model of key aspects for a successful teaming between humans and automation (based on Rieth & Hagemann, 2022).

The model was derived on the basis of an international interview study with experts. It shows which aspects can contribute to the successful realization of human-autonomy teaming, both on the human side and on the automation side (for more details, see Rieth & Hagemann, 2022). The model does not claim that all aspects must be fulfilled simultaneously, but rather represents a collection of aspects that are, from the experts' perspective, conducive to achieving a teaming. One key aspect is that the human operator brings system knowledge, i.e., knows the system logic, capabilities, and limitations. Moreover, there should be a willingness to disclose personal data so that the automation can provide needs-based support on the basis of this data. Another key aspect on the automation side is that it should work safely and reliably, as otherwise problems can arise with regard to humans' trust in automation and their willingness to use it. In addition, the automation's behaviour, mode, and intentions should be made transparent to the human through the interface design. For successful teaming, it is also beneficial if the automation can explain the reasons that led to an automated decision in a comprehensible way. Moreover, it should ideally be able to consider human needs and emotions. For example, if the human is tired, it could provide more support. In order to achieve a teaming, the human and the automation should know and understand the overall work target. In addition, for the realization of a teaming, it is beneficial if the current and future (mental) states can be mutually estimated. It is also conducive to teaming if the tasks are assigned in a human-centred manner according to the strengths of the human being and if this function allocation can be flexibly adjusted depending on situational conditions.

HUMAN-AUTONOMY TEAMING IN THE RAIL INDUSTRY

Similar to air traffic controllers, signallers also operate in a safety-critical area with a high level of responsibility. They also supervise and navigate traffic with the help of complex technologies and ensure that traffic flows safely, efficiently, and in an orderly manner. Similar to air traffic controllers, they undergo intensive training to be able to perform their job. Thus, here, we are also dealing with a highly qualified group of employees whose work is being fundamentally changed by the implementation of increasing automation.

While air traffic control primarily uses automation that operates at the level of information analysis, for electronic interlockings assistance systems already exist that additionally take over decision-making and action execution functions, such as the automatic route setting. This system sets the routes for all trains listed in the control plan on the basis of data entered in advance. If no entries are made for waiting times or trains to be allowed to pass, the system usually decides on the basis of the first-come-first-served principle. If the safety-relevant conditions are met, the interlocking automatically sets the route and allows the train to run. The train control system is therefore not only a system for decision support but also for action execution. The automation only works if data for a train are available and under complete technical security. If this is not the case, signals remain in hold and train traffic comes to a standstill until humans intervene to correct the situation.

The difference to the degree of automation in air traffic control may be explained by the fact that in train control, with regard to the direction of movement, only a two-dimensional space has to be considered and that there is a safe state in standstill according to the motto "A standing train is a safe train". On the other hand, in air traffic control, the three-dimensional space adds another dimension of complexity. Since humans continue to bear responsibility and a safe state in the air similar to standstill in the rail industry cannot be guaranteed, a higher degree of automation at the stage of action implementation is not currently being aimed for in air traffic control. Despite all the automation efforts, the signallers remain an essential part of the railway industry. For example, due to safety standards, the train control system acts separately from the disposition system. It therefore usually has no access to current timetable and delay data. In the case of conflicts caused by delays, the first-come-first-served principle is not always appropriate. In this case, a manual disposition by the signallers is required. For example, they have to deactivate or reactivate the train control at individual signals or edit the routing plan. The same applies in the event of malfunctions. Then the train control system is not allowed to continue operating automatically and the human has to takes over the manual control. As a result, first tendencies of a teaming are emerging here: Signallers and automation work interdependently towards a common goal: a safe, efficient and orderly traffic flow.

How this teaming between humans and automation can be strengthened in the future can be discussed with the help of the key aspects of the above model. While automation as a team member already takes over extensive, simple tasks and thus considerably relieves signallers in regular operation, the transparency of train control in the sense of communication of the planned and next executed actions could still be improved. The top priority should be to focus on the human operators and their needs so that teaming can continue to be designed in a human-centred way in the future.

CONCLUSION

The effects of new automation technologies on human perception – and thus on their motivation, job satisfaction, and performance – depends on the specific work design (Gagné et al., 2022; Parker & Grote, 2022). If a human-centred approach is chosen, contrary to automation myth #4, even a teaming between humans and automation *is* possible. Referring to the introductory example from air traffic control, one solution to the problem of disenfranchisement could be, for example, to allow air traffic controllers to flexibly allocate functions between themselves and the automation according to their needs (cf. Rieth, 2022). For example, in stressful traffic situations the Arrival Manager could assist them, while in calm traffic situations and for the purpose of regular practice they take over the task of sequencing themselves. The above model specifies which aspects can be conducive to the realization of teaming. This might also be relevant in the rail industry in order to be able to design the socio-technical system to function as a team member in the future.

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