AUTOMATION MYTH BUSTING SERIES

German Centre for
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EUROPEAN UNION AGENCY FOR RAILWAYS

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AUTOMATION MYTH #2
= Automation technology can operate mainline railways without human involvement

The Changing Role of Staff in Automated Railway Operation and why Human Cognition is Here to Stay

SUMMARY

Automated mainline railway operation is challenging the traditional role of the operational staff ensuring safe and punctual service. Nevertheless, there are sound operational, economic, regulatory and societal reasons for valuing and maintaining central contributions of human staff to railway operation in future automated service. Instead of a linear transferal of tasks from the human to the automation technology a human-machine collaboration setting becomes apparent that enables both, automation-driven benefits in terms of capacity or energy consumption and benefits in terms of efficient human intervention in case of operational uncertainty, where human decision-making and communication skills are key to safety.

AUTHOR

Dr. Niels Brandenburger

is Human Factors Expert at the German Aerospace Center (DLR e.V.) at the Institute for Transportation Systems. He works on empirically investigating, operationally defining and practically implementing the human contribution to automated railway operation on the mainline.

niels.brandenburger@dlr.de

INTRODUCTION

Think of the last time you tried to get something 100 percent right. I assume the first 70 to 80 percent of the work went quite well and then the trouble started, you spend more and more effort to accomplish less and less progress. Did you get to 100 percent in the end? Or did you stop at 95 percent, because you a) were just not able to do the last five percent on your own or b) the effort was just too big to be worth it? The bottom line is that there are good reasons why we collaborate with others to achieve our goals. It is so much more efficient and smarter than trying to be a classical "know-it-all". The same logic applies to human-machine collaboration, where human experts and automation technology collaborate to jointly achieve a certain goal by investing a reasonable amount of resources.

SCIENTIFIC FOUNDATION

Most automation taxonomies implicitly convey the idea that the introduction of automation technology is a one-way ticket. Levels of automation, representing a common and fundamental automation taxonomy, are defined as "a continuum of levels, from the lowest level of fully manual performance to the highest level of full automation" (Parasuraman et al., 2000, p. 287). In other words, the level of automation describes to what extent a system is executing a function autonomously. Stages of automation refer to the information-processing stage to which the automated functions can be attributed (Parasuraman et al., 2000). The stages are based on a simple four stage model of human information-processing comprising sensory processing, perception, decision-making, and response selection that directly translate into the four stages of automation: information acquisition, information analysis, decision selection and action implementation (Parasuraman et al., 2000). Thus, an automated functionality can be classified according to its level of

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automation and the information-processing stage it is executing, captured by the stage of automation. Finally, the concept of degrees of automation integrates both former concepts—levels and stages— into one continuum, in the sense that "higher degrees of automation can be accomplished by both higher levels within a stage and by including later stages" (Wickens et al., 2010, p. 389). The notion of degrees of automation (see Onnasch et al., 2014) represents the latest well-established stance on classifying automation. All of these taxonomies seem to draw a trajectory on which human involvement is gradually replaced by automation technology.

CURRENT DEVELOPMENTS IN THE RAIL CONTEXT

The same logic applies to the railway specific Grades of Automation or GoA (VDE,2015). The taxonomy incorporates an aggregation of tasks into four functional categories—safe movement, speed control, door operation, and disruption mitigation— that need to be executed to operate safely (VDE, 2015). With each consecutive GoA more functional categories and autonomy are attributed from the members of staff—in most cases the train driver—to technological systems. Brandenburger and Naumann (2019b) broadly summarised the operational task environment across all four GoA: "At GoA1, the train driver in the cabin is responsible for the train ride including speed adjustment, (…) [while] an automatic train protection system (ATP) is monitoring adherence to speed limits in the background. At GoA2, ATP is side lined by (…) automatic train operation (ATO) functionality responsible for automatic speed adjustment, (…). The train driver in the cabin remains in charge of monitoring instruments and track integrity, thus ensuring the safety of the trip. At GoA3, the train driver is no longer situated in the cabin (…). Solely, the door closure is checked by a train attendant stationed within the running train. GoA4 is characterised by complete absence of staff on board and the train ride is completely executed by automation technology, hence the term unattended train operation (…)" (Brandenburger & Naumann, 2019b, p. 289). This general linear logic of subsequent task reallocation from the human to the automation may hold for certain applications, but does this logic really hold for transportation, more specifically the railways, with a wide societal audience as stakeholders with all kinds of perspectives on issues around trust, liabilities etc.?

Yet, very early on an idea known as the Fitts list (Fitts, 1951) or MABA-MABA lists ("Men are better at, Machines are better at") went into a different direction of thinking about human-machine collaboration by trying to figure out which actor is better at what task. From my point of view, this direction of thought focusing on a proficiency-based task allocation provides a more promising approach to finding the right balance of human machine collaboration in our socio-technical railway system, enabling safe, efficient and secure future railway operation. Following this train of thought, a line of research (see literature review in Brandenburger, 2021) started investigating from a user-centred perspective in what role the human staff could best contribute to safe and reliable automated railway operation such as GoA3 or GoA4, given certain operational, economic, regulatory and societal premises. Operationally, human decision-making seems vital due to the dynamic real-world constraints mainline railway is operating under requiring constant situation assessment and replanning. Economically, automating the operation in every possible system state seems overly costly at a minimum, and just not particularly smart as pointed out in the introductory example. From a regulatory point of view, legal jurisdiction currently simply calls for human supervision of railway operation to maintain high safety standards that are valuable and probably only for negotiation, once a human-machine collaboration setting can prove adherence to these standards in a watertight fashion. First empirical results suggest e.g. a more balanced operator workload, reduced fatigue and supposedly quicker subsequent reaction times to critical stimuli [e.g. brake indications on the European Train Control System (ETCS) Driver Machine Interface (DMI)] in GoA3/4 setting compared to GoA2 (Brandenburger, 2021, see figure 1). Furthermore, a study found positive expected effects of GoA3 on job satisfaction in comparison to GoA2 (Brandenburger & Naumann, 2018). Last but definitely not least, society as a whole demands high safety standards (CE Delft, 2018) which are competing with mainly economic objectives - automation just needs some tolerable margin of error to be economically reasonable. This margin of error needs to be monitored at times through human staff. In light of these premises, the idea of situation-specific human intervention into an otherwise automated GoA3/4 operation was developed (Brandenburger & Naumann, 2018) and empirically evaluated (Brandenburger, 2021). At the heart of this idea lies the simple notion that the automation itself needs to detect its own system limits and basically calls for help from the human staff situated remotely once an operational situation emerges that exceeds automation capability and thus exceeds the tolerable margin of error.

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Personally, I feel ATO over ETCS or GoA2 and to some extent GoA4 falls under the first 70 to 80 percent as referred to in the introductory example in the development process of mainline railway automation. Suppliers have great engineering minds working on sophisticated ATO speed control systems. They will presumably figure out how to outdo human staff in driving a train under routine situations with an ATP such as ETCS as a safety layer beneath the ATO. Nevertheless, as soon as we start thinking about situations where full ATP protection such as ETCS FS (full supervision) is not available, we are encroaching on the uncomfortable part of the railway automation task. The notorious last 20 to 30 percent are marked by e.g. unavailable ATP protection, insufficient localisation or object detection, difficult to diagnose technical malfunctions on both track and rolling stock side, or abnormal states of the physical and social environment that the railway is operating in such as weather or social phenomena such as light-hearted sports fans (e.g. running / pushing at the platform or opening doors by force). To tackle these remaining 20 to 30 percent human problem-solving, decision-making and communication will remain vital in automated railway operation. Research and engineering needs to establish which organisational, physical and cognitive work environment is best suited to enable this human contribution to automated railway operation safety and efficiency. On these questions current research suggests that a GoA3/4 work environment for human staff can be superior to a GoA2 and in some aspects even to the current GoA1 work environment in terms of workload and subsequent fatigue and even aspects of performance (Brandenburger, 2021, see figure 1). Recently, various research (e.g. Grippenkoven et al., 2020) and development projects, amongst others TC-Rail (Pacaux-Lemoine, Gadmer & Richard, 2020), 5GReallabor[1] or ATO-Cargo[2] in Europe, have started to employ the available scientific insights on operator workload, fatigue and system performance to move from theory to practical test implementation of this idea on GoA4 mainline operation plus human remote control as a contingency layer.
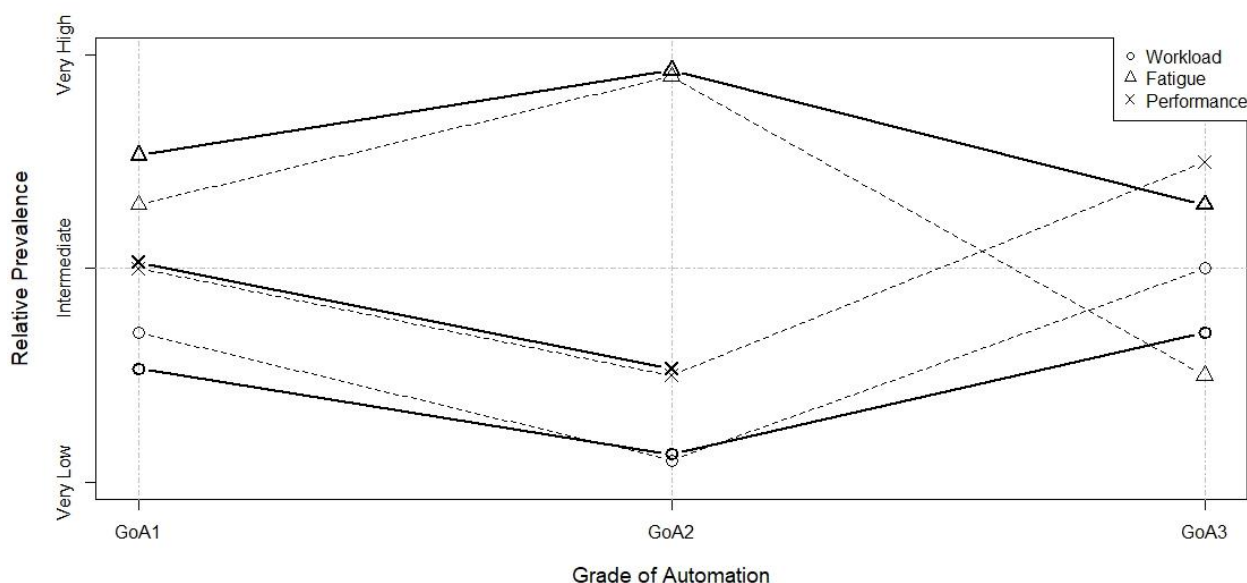

Fig. 1: Effects of Grades of Automation on Workload, Fatigue, and Performance. Note: Schematic illustration of hypothesized (dotted lines) and observed (solid lines) effects of Grades of Automation (GoA) on workload, fatigue, and human failure performance. The relative prevalence did not convey precise scores, but represented an indication of directions and strengths of the effects. A comparable performance metric for GoA3 was missing at the time of data collection, therefore GoA3 performance is not incorporated in the graph above. Source: Brandenburger, 2021.

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[1] 5GReallabor: https://verkehrsforschung.dlr.de/de/projekte/projekt-ato-cargo-erprobung-automatisierter-gueterzuege
[2] ATO Cargo: https://verkehrsforschung.dlr.de/de/projekte/5g-reallabor/mobilitaet

CONCLUSIONS

The fact that various current projects are implementing railway automation technology alongside a human task spectrum emphasizes that human staff does have a central role in future automated mainline railway operation for operational, economical, regulatory and societal reasons. This role in particular comprises decision-making, communication and malfunction mitigation in degraded operations (Brandenburger & Naumann, 2018). Yet, when thinking about human-machine collaboration in this context, it seems crucial for safety and also for occupational acceptance of that new human role to avoid a mismatch between technological task execution on the one hand and legal human responsibility on the other hand. Wherever possible, actions and the responsibility for those actions should go in parallel.

With this is mind research and development looking at shaping this new human role in railways has great potential to reap the benefits from both domains whilst maintaining high safety standards: automation can bring benefits in terms of capacity and energy consumption. Integrating human and organisational factors can mitigate the risks due to operational uncertainty and at the same time improve job satisfaction due to a coherent and purposeful human role definition (Brandenburger, 2021).

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