FROM GOA2 TO REMOTE OPERATION: WORKPLACES IN HIGHLY AUTOMATED RAIL

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During the last years, the projects *Next Generation Railway System*, *Next Generation Train*, and *Digitalization and Automation of the Railway System*, enabled a series of studies regarding the train driver's workplace at the German Aerospace Center. This research focused the changes in train drivers' tasks and workplace environments as well as changes in demands on train drivers with increasing digitalization and automation of the Railway System. Increasing grades of automation impact the ways in which the staff can contribute to overall system performance and safety (Brandenburger, Naumann, & Jipp, 2019).

First, we present experimental results on the effects of intermediate grades of automation (GoA2, International Association of Public Transport, 2012) on train driver performance, fatigue, workload, situation awareness and attention allocation. At GoA2, Automatic Train Protection (ATP) is side lined by technological automatic train operation (ATO) responsible for automatic speed adjustment, while the train driver in the cabin remains in charge of monitoring instrument panel and track, thus ensuring the safety of the trip. This implies continuous monitoring of an automated system but at the same time having to react quickly and correctly in a critical situation. In line with broader theory, our results reveal unfavourable effects on workload, fatigue and performance (e.g. Brandenburger & Jipp, 2017; Brandenburger, Thomas-Friedrich, Naumann, & Grippenkoven, 2018).

Second, these results concerning GoA2 are compared to research on high grades of automation and its effect on the involved human operator. There, we currently focus on GoA3, where the train driver is no longer

available in the cabin, while speed adjustment, track integrity checks and all safety- relevant tasks are executed by ATP and ATO technology. Nevertheless, the driverless operations need to be monitored from a control room. We propose a role change from the train driver to the role of a train operator, a member of staff that is automatically requested by the driverless trains to remotely diagnose or manually drive any train in a particular area, once the ATO functionality reaches its limits and disruptions occur (Brandenburger & Naumann, 2018b). The task environment of a train operator comprises tasks that are not necessarily related to a particular train (e.g. communication, planning, or monitoring the traffic in the area) as well as tasks that come up after manual intervention is requested by a particular train in cases of irregularity (e.g. on- sight driving, speed adjustment, communication with passengers, or diagnosis; Brandenburger & Naumann, 2018a). At the German Aerospace Center, we developed a prototypical workplace environment for the future train operator. This prototype is in continuous further development and improvement. Here, the current state of the design will be presented, and first results on the effects on the train operator will be contrasted with our results for GoA2.

In summary, we assume that limited capacity gains as well as the human factors challenges of GoA2 may turn the favourability towards GoA3 operation with an operator role that enables a more effective human contribution to the overall railway system performance, safety and reliability (Brandenburger & Naumann, 2019).

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