11th WCRR World Congress on Railway Research 2016 29th May – 2nd June Milan - Italy

Future information and assistance systems for train drivers and evaluation of their usability

Anja Naumann[1], Jan Grippenkoven[1], Karsten Lemmer[1]

[1] German Aerospace Center (DLR), Institute of Transportation Systems, Braunschweig, Germany

Contact: anja.naumann@dlr.de

Abstract

Even though train protection systems are used to avoid critical situations, the train driver remains responsible for the continuous monitoring of signal aspects and derivation of suitable actions. This requirement persists, although the position of signals shifts more and more from external signals to in-cab displays, especially with advanced levels of train protection and automatic train control. Errors in the detection and interpretation of signal- or display information and driver distraction may lead to severe accidents.

Aim of our research at the Institute of Transportation Systems (ITS) is to develop innovative concepts of the train driver's workplace in order to secure a safe and efficient railway system that keeps the driver 'in the loop'. Therefore, we follow a user centred approach. The train driver participates directly in the development and evaluation process of new systems supporting the work in the driver's cabin.

Using our driver's cabin simulator recently built at the ITS as a flexible vehicle platform in a simulation environment, we are able to investigate the driving behaviour and the train driver's information processing during his or her task. From the results, we derive concepts in order to optimize the presentation of necessary information and give recommendations how to assist the train driver. In the present paper, first concepts for supporting the train driver in keeping attention and also our simulation environment and the methodology used are described.

1. Introduction

Today, train protection systems are often used to avoid critical situations in railway traffic. However, the train driver remains responsible for the continuous monitoring of signal aspects and the derivation of suitable actions. This requirement persists, although monitoring shifts somewhat from lineside signalling to in-cab displays, due to the ongoing implementation of advanced levels of train protection and automatic train control (e.g., continuous train control system LZB and European Train Control System ETCS, level 2). In these cases, especially mode transitions (like switching from full- to limited supervision or Class B-systems) need to be anticipated and detected alongside other possible disruptions. Errors in the detection and interpretation of such signal or display information may lead to severe accidents, as some of the latest incidents demonstrate.

Signals passed at danger (SPADs) are one of the most common causes of incidents in railway operations and are largely attributed to errors of the train driver. The German railway accident examination center [1] for example, has registered 462 non-technical failure SPADs out of a total 752 reported incidents in 2011. In 2012, out of 723 incidents 415 were SPADs [2]. Retrospective investigations concerning the development of these incidents uncover complex and highly individual interactions between various performance shaping factors, such as type of signal, time of day/ year, weather conditions, driver experience and other person related aspects. A closer look reveals that besides these factors relating to either the environment or the person, errors also often result from a disadvantageous human machine interaction with regard to operational demands and monitoring tasks.

Great effort has been put into the prevention of passing signals at warning and stopping aspects by the development of assistance or automation technology. Train protection systems serve, for example, to signalise and monitor braking curves, monitor speed restrictions and stops at signals or to initiate a forced emergency brake. However, although these systems have helped mitigating the severity of consequences of SPADs, they have not eliminated the issue [3,4]. Catastrophic accidents, like the Hordorf train collision in Germany in 2011 [5] or the derailment in Santiago de Compostela in 2013, can still occur if a train driver fails to attend to rail-side signals where such technologies fail or have not or not yet been equipped. Even with well operating systems in place, inadequate interpretations of and reactions to signal aspects can still cause critical incidents, for instance by “slipping” past a signal at danger and its associated safety overlap or by unjustified releases of train protection braking.

In order to prevent critical incidents, train drivers may not entirely rely on the train protection infrastructure and still need to attend signal aspects and speed limits in their environment. In order to fulfil this task, train drivers need to be familiar with the route they are driving, the surrounding area, signal positions, speed limits as well as the position of curves, stations, constructions sites and other speed restriction sections.

Aim of our research at the Institute of Transportation Systems (ITS) at the German Aerospace Center (DLR) is to develop innovative concepts of human-machine interfaces at the train driver’s workplace in order to secure a safe and efficient railway system that keeps the driver ‘in the loop’. To reach this aim, we follow a user centred research and design approach. This approach is described in the following.

2. Research approach

2.1 User Centred Design

A comprehensive perspective in railway systems research requires an approach that does not focus solely on technology. It also has to consider human operators as a crucial impact factor. The Rail Human Factors research at DLR follows a user centred design approach, involving the personnel in the rail system. With this human-centred approach, we pursue the goal to make a valuable contribution towards the user-friendly, safe and smooth rail transport of tomorrow [6].

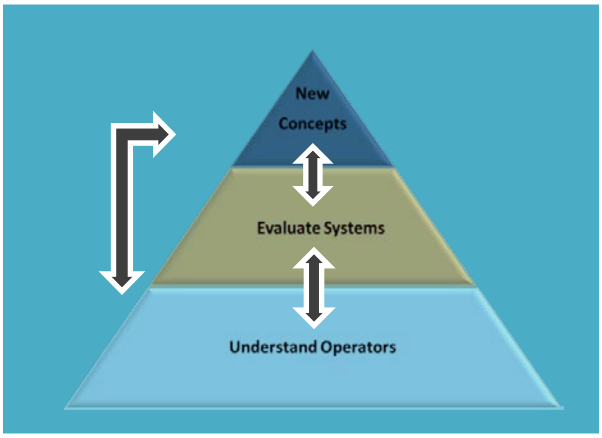

Figure 1. Rail Human Factors Approach [6]

Our research is based on three key issues (Fig. 1): understanding the user (operator), evaluating existing systems, and developing and testing new concepts. Moreover, we transfer established methods from psychophysiology and user-centred design to these three key points of evaluation and design and develop new methods for evaluation and design (e.g., questionnaires, simulation environments). The approach is described in detail in [6].

2.2 Developing information and assistance systems for train drivers

Based on our user centred design approach, in order to develop future human-machine interfaces for the train driver or to refine existing ones, we execute the following steps:

(1) investigate cognitive functions and procedures implied in the train driver's work,
(2) develop strategies for error prevention and the design of driver assistance and advisory systems in rail traffic,
(3) translate the strategies into first interface design concepts,
(4) evaluate the concepts, e.g., regarding distraction potential, usability, and intuitive interaction,
(5) refine the concepts according to the evaluation results.

In the following, an example for the application of this process will be described.

2.2.1 Enhancement of the German punctiform train protection system interface

Occasionally, in the context of incident and accident analysis, specific aspects in the design of train protection systems are mentioned as possible causes of attention deficits and resulting errors of train drivers (e.g., [7,8]). In Germany, the punctiform train protection PZB 90 is the most widespread train protection system. Usually a distant signal informs the driver of the signal aspect of an upcoming main signal. He or she has to regulate the train's speed and actuate PZB buttons related to the signal aspect. The PZB automatically elicits a forced brake when either the PZB buttons are not actuated or a violation of the required braking curve is detected on approach towards the main signal after passing a distant signal with a warning aspect. The PZB is designed in order to mitigate human errors in attending the signals. Still, it does not prevent human errors with regard to an inadequate brake operation. Thus, signals passed at danger remain one of the primary causes of railway incidents. In order to develop a new concept of assisting the train drivers in keeping attention we followed the process presented in 2.2:

(1) In a first step we conducted a deeper analysis of the attention processes and the interrelations of causes regarding attention deficits in the context of the train drivers' workplace. The result is a description of the processes in a system related onset model of attention deficits [9]. Based on the analysis we drew conclusions concerning disadvantageous design features of the German punctiform train protection system (PZB). Subsequently, a discussion group with train drivers concerning these findings was conducted. One key result is that train drivers sometimes tend to confirm the PZB buttons "blind", without previously attending all necessary information in the environment. Especially the aspect of the distant signal is sometimes not properly attended. This can lead to dangerous incidents.
(2) In a second step we translated the most important conclusion from the earlier analysis into a strategy for keeping the train drivers' attention: all signal aspects should be actively confirmed.
(3) In a third step we developed ideas how to transfer this additional confirmation action in an input for the human-machine interface (HMI) of the PZB. The ideas (a signal specific shifting lever, touch screen or gesture input) were selected as most promising (see Fig. 2) and refined after discussing them with train drivers. Finally we decided for the manual shifting interface as a new HMI strategy that could replace the current version of the PZB interface. The manual shifting system consists of four different positions, three specific positions for each possible aspect of the distant signal and a neutral rest position (Fig. 3).

(4) The shifting system was implemented as a prototype and evaluated in our train drivers' cabin simulation environment RailSET. The current version of the PZB was compared to the new alternative shifting interface.
(5) Finally, conclusions for refinement of the tested shifting system were derived. These recommendations will be implemented in a newer version of this prototype.

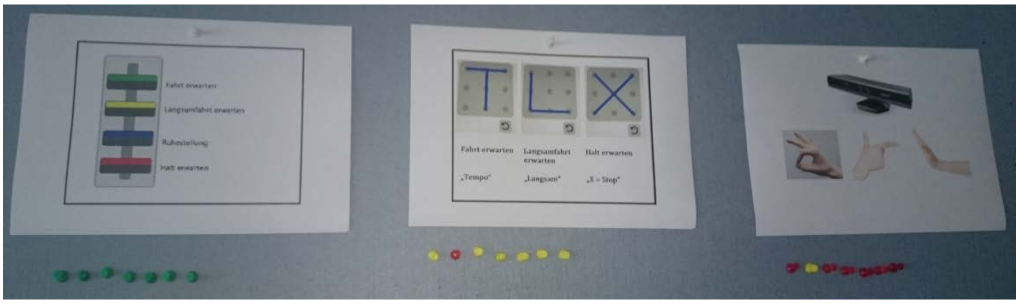

Figure 2. Shifting lever, touch screen, and gesture input as concepts for signal aspect confirmation in the train protection system PZB. The shifting interface was liked most by the train drivers (green pins).

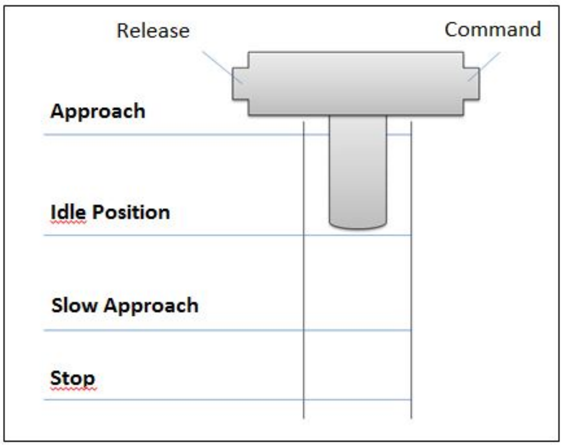

Figure 3. Shifting interface for confirming the signal aspect seen by the train driver. Signal aspects can be: the next main signal shows either approach, slow approach or stop (signal at danger).

2.3 Our simulation environment: The AIM Modular Mockup Rail

For executing the steps (1) and (2) in the process of developing new advisory and assistance systems (see 2.2), meaning the investigation of train drivers' cognitive processes as well as the evaluation of prototypes and systems, we will be able to use our driver's cabin simulator AIM Modular Mockup Rail soon. The simulator has recently been built at the ITS in the context of the Application Platform Intelligent Mobility (AIM). It is a flexible vehicle platform in a simulation environment with which we are able to implement any variation of cabin interior and control systems. This is a novel and unique feature compared to commercial training simulators. Figure 4a shows the perforated plates for mounting any kind of control system, e.g., in the form of touch-screen terminals. Also, with the perforated ground plate, flexible positions of the foot pedal and the driver's seat, for example, become possible. Figure 4b shows the driver's position and a potential arrangement of control systems around him. With this setup, different arrangements of the control panels in the cabin can systematically be compared. Additionally, a variety of driving environments and situations can systematically be simulated and displayed on a 360 degree vision system.

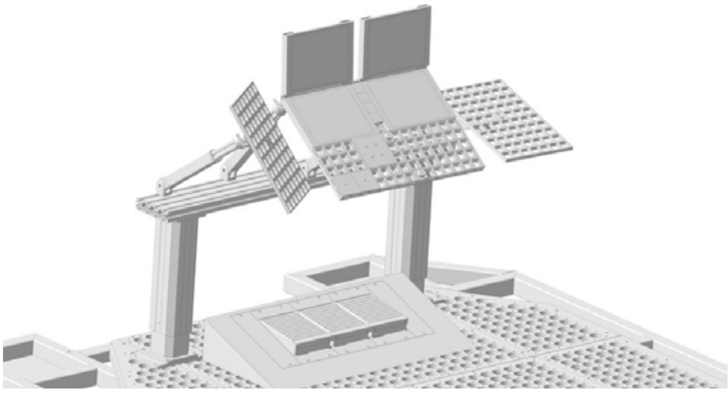 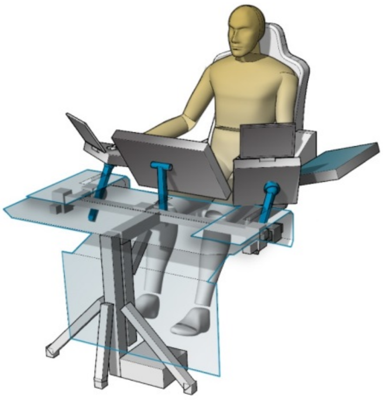

Figure 4. a) perforated plate for mounting interior components, e.g., control panels;
b) train driver's position and potential arrangement of control panels

The AIM Modular Mockup Rail can be used in three different setups, namely as a:

1) stand-alone mockup including driver's cab (Fig. 5) and screens or projection system displaying the virtual driving environment in front,
2) mockup in the ITS Virtual Reality Lab with a 360 degree vision system, or
3) mockup in the ITS Motion Simulator, mapping real dynamics of acceleration onto the virtual driving environment for a highly realistic driving experience.

Figure 5. AIM Modular Mockup Rail including driver's cab

In addition to developing new approaches for future information and assistance systems, with our AIM Modular Mockup Rail we can also conduct evaluation studies of existing control panels or concepts in development. In collaboration with rail operators and manufacturers, we can implement any cabin design in our simulation environment and test the usability (user friendliness) and ergonomics. The mockup can also be used for evaluating light rail control systems and cabin design.

3. Outlook

With the ongoing rollout of ECTS transitions between different train protection system and mode transitions will become more and more important and demanding for the train driver. In an upcoming study, we are going to develop assistance for the train driver for coping with theses transitions and keeping his or her awareness of the actual system state and protection/ automation level. In this study, again we are going to follow the development and evaluation steps of the user-centred approach described in chapter 2.2. The prototype of the developed assistance concept will be evaluated in our simulation environment AIM Modular Mockup Rail.

With the AIM Modular Mockup Rail, we are planning to conduct evaluation studies in collaboration with rail operators and manufacturers in order test, for example, the usability, ergonomics, intuitive interaction, and efficiency of systems or concepts in development. Aim is to give recommendations for further development of the respective systems and the cabin design as a whole.

4. References

[1] Eisenbahn-Unfalluntersuchungsstelle des Bundes (2012). *Eisenbahn-Unfalluntersuchung Jahresbericht* [Railway accident analysis annual report] 2011. Bundesministerium für Verkehr, Bau und Stadtentwicklung, Bonn, Germany. Online: http://www.eisenbahn-unfalluntersuchung.de/EUB/DE/Publikationen/Jahresberichte/jahresberichte_node.html

[2] Eisenbahn-Unfalluntersuchungsstelle des Bundes (2013). *Eisenbahn-Unfalluntersuchung Jahresbericht* [Railway accident analysis annual report] 2012. Bundesministerium für Verkehr, Bau und Stadtentwicklung, Bonn, Germany. Online: http://www.eisenbahn-unfalluntersuchung.de/EUB/DE/Publikationen/Jahresberichte/jahresberichte_node.html

[3] RSSB - Rail Safety and Standards Board (2012). *RSSB Annual Safety Performance Report, 2011/12 - A reference guide to safety trends on GB railways*. Rail Safety and Standards Board, London.

[4] RSSB - Rail Safety and Standards Board (2013). *RSSB Annual Safety Performance Report, 2012/13: A Reference Guide to Safety Trends on GB Railways.* Rail Safety and Standards Board, London, United Kingdom. Online: http://www.rssb.co.uk/SPR/REPORTS/Documents/ASPR_2012-13_FullReport.pdf

[5] Eisenbahn-Unfalluntersuchungsstelle des Bundes (EUB) (2011). *Unfallbericht Zugkollision Überleitstelle Hordorf / Strecke Magdeburg Hbf – Halberstadt am 29.01.2011* [Accident report train collision Hordorf], Bundesministerium für Verkehr, Bau und Stadtentwicklung, Bonn.

[6] Naumann, A., Grippenkoven, J., Giesemann, S., Stein, J., and Dietsch, S. (2013). Rail Human Factors-Human-centred design for railway systems. *12th IFAC Symposium on Analysis, Design, and Evaluation of Human-Machine Systems*, Las Vegas, August 2013.

[7] Baysari, M. T., McIntosh, A. S., and Wilson, A. R. (2008). Understanding the Human Factors Contribution to Railway Accidents and Incidents in Australia. *Accident Analysis and Prevention, 40*, 1750–1757.

[8] Edkins, G. D. and Pollock, C.M. (1997). The Influence of Sustained Attention on Railway Accidents. Accident Analyses and Prevention, 29 (4), 533-539.

[9] Giesemann, S. and Naumann, A. (2015). Zugsicherungssysteme – Assistenz für Triebfahrzeugführer? [Train Protection Systems – assistance for train drivers?] *Kognitive Systeme, 2015-1.* DuePublico.