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Form follows vision – user-centred interface design for rail traffic controllers´ workplaces

Jan Grippenkoven*. Anja B. Naumann*.
Abhinav Bhattacharyya. Karsten Lemmer*.**

**German Aerospace Center, Institute of Transportation Systems,*
Lilienthalplatz 7, 38108 Braunschweig, Germany
(Tel: +49 531 295 3507; e-mail: jan.grippenkoven@dlr.de)

***Assam Engineering College*
Jalukbari, Guwahati-13, Assam, India

Abstract: In our Rail Human Factors approach, we define the human as the starting point for our interdisciplinary research on the design of human-machine interfaces in railway systems. One key focus of this approach is on the future workplace of the rail traffic controller. In this paper, a collaboration project between human factors scientists and trained rail traffic controllers is presented. Based on the methodological background of usability engineering, an innovative interpretation of the user interface of the German electronic interlocking system (ESTW) was developed. First prototypical propositions for the design of a future interlocking system were generated in an iterative process of design and feedback phases. Here, we made use of the advantages of the domain expertise of the usability experts as well as the rail traffic controllers. The resulting design is characterized by a decluttered central display / control panel on a single monitor.

Keywords: Communication systems, Human-machine interface, Human Perception, Human supervisory control.

1. INTRODUCTION

In the railway system, various generations of interlocking systems can be found nowadays. Right from the introduction of the first mechanical interlocking systems up to the development of the electronic interlocking system, the appearance of the workplace interlocking system has continuously changed and developed. The first electronic version of an interlocking system in Germany was released in 1986. Since these days, the field of computer technology has developed rapidly. The computational capacity of computers for home purposes, for example, has increased significantly and has regularly doubled on an average every 18 months in the period from 1986 to the present (Hilbert & Lòpez, 2011). Also, the storage capacity of computers and the performance of display media have continuously increased. In contrast to these great technological leaps, user-friendliness of the majority of human-machine interfaces in both the private and professional context has developed rather slowly. During the various stages of development it has been seen that although enough focus has been given to the technological progress and functionality of electronic devices, a further development of the usability of its user interfaces and the intuitiveness of the interaction is often neglected. For the user, the variety of new and additional functions in electronic devices is often difficult to decipher and handle. The development of interlocking technology in Germany since 1986 in terms of increase in the computational capacity has been very beneficial. In addition to that, the introduction of new display media, especially tubeless monitors, save a lot of space in the control centres nowadays.

Fig. 1. Major steps in the development of the human machine interface in interlocking systems.

Nevertheless we also find a major imbalance in the rail traffic system between progress in the areas of technology (hardware) and progress in the usability of the systems. No significant changes in terms of the operating logic and user friendliness of the electronic interlocking system have been made for a long period of time (Fig. 1). While similar deficits have already been attended for some time in aerospace and automotive industry, where progress can be found in the field of human factors, the development of usability of systems in the railway sector is found to be comparatively slow. This is partly due to the long product lifecycles and complex approval processes in the railway industry.

Considering the progressive trend towards a strong automation of its systems, the nature of tasks of the railway staff has changed significantly over the last few decades. There has been a shift from the conventional nature of physical tasks to passive monitoring tasks that involve monitoring of a properly functioning (automated) system. In this context, it is increasingly important to present system dialogs, overviews, feedback, and other information on the monitors of the system in an understandable and easily-detectible manner. A key task is to develop a design of the workplace of the rail traffic controller in a way that on the one hand reduces cognitive load and on the other hand ensures a constant state of situation awareness in the operator, meaning his or her perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the projection of their status (Endlsey, 1995). The operator must be enabled to get a complete overview of the current situation at any moment in time, to be able to act appropriately and fast in case of emergencies and alarms. At the Institute of Transportation Systems of the German Aerospace Centre (DLR), we are therefore conducting research in the field of intuitive human-machine interaction for railway applications.

As a part of this research, a usability engineering project was supervised at the University of Applied Sciences Erfurt during the winter term 2012/2013. The aim of this project was to design a new user-friendly human machine interface for the electronic interlocking system with a methodically structured framework at hand. In this collaboration, the expertise of the DLR in the field of usability engineering has been successfully merged with the knowledge of the electronic interlocking system of six actively involved rail traffic controllers. The pivotal question of the project that the rail traffic controllers had to deal with was: ‘How should a user-friendly rail traffic controller’s workplace of the future look like, if you use only a single monitor to display all the necessary information?’

2. GENERAL RESEARCH METHODOLOGY

Since the current user interface of the electronic interlocking system as operated by DB Netz AG (the major rail network provider) in Germany usually consists of a total number of eight monitors, the task to reduce the set of monitors to a single one posed a big challenge to everyone involved in this project. The eight monitors of the electronic interlocking system are generally used to display the current railway operations situation, including various subsystems of different safety integrity levels. A lot of information is provided simultaneously on the available displays. Besides the monitors for the control of railway operations (in which among other content the railway infrastructure of a particular area is topologically represented), there are additional monitors, containing windows for different tasks. In order to achieve the desired reduction of the amount of information that has to be monitored and to enhance usability at the same time, the option of how to integrate different subsystems had to be considered in the project.

At a first glance the requirement of reducing the content of the user interface significantly may appear somewhat radical. The rationale behind this strict requirement was to force all participants to let go of the given conventions in the design of the human machine interface of the current electronic interlocking systems. Instead, participants were encouraged to generate creative new approaches to display the information necessary. Taking a step back in this context and reconsidering the essential tasks of the rail traffic controller in order to create a new, user centred interface was supposed to be a necessary precondition to develop a new concept of the electronic interlocking interface.

The methodology generally applied to usability studies at the DLR is based on the usability lifecycle, with its iterations of concept and feedback phases (Mayhew, 1999). The development of a new system always starts with an analysis of all tasks that a particular operator has to deal with at a given workplace with its particular systems. This step is followed by the development of first design concepts to illustrate how the overall interaction with system could be improved in terms of its usability. These ideas are then incorporated in a first prototypical design sequence of the most essential functions and interactions. This step by step approach of developing a new user interface is characterized by its multiple iterations of conception phases and revision. The feedback of the system experts is the key factor for improvement and therefore it is consequently included in all stages of development (Fig. 2).

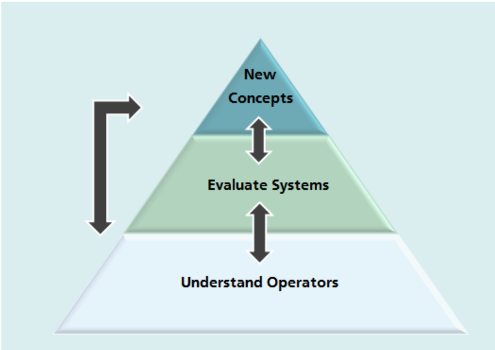

Fig. 2. Iterative approach of DLR in the field of usability engineering.

3. USABILITY ENGINEERING PROJECT: ELECTRONIC INTERLOCKING SYSTEM

In the first step of the development of the new human machine interface for the interlocking system in this project, the task was to define user requirements. Interviews with experts (rail traffic controllers) as well as observations of their daily working routine were conducted. A structured task analysis was performed over all the activities of a rail traffic controller. The tasks (both active tasks and monitoring tasks) were then categorized, using a matrix system along the dimensions of "possible criticality / importance" and the "frequency of occurrence". This was done to identify the most important subtasks that have to be included in the redesign of the human machine interface of the electronic interlocking system (Fig. 3).

	Often	Regularly	Seldom
High	Track route locking	Operating supplementary signals	Ordering emergency stop of train
Medium	Train identification entry	Activation of level crossings	Announcing change of tracks
Low	Entering reason for delay	Logging in	Opening communication window

Fig. 3. Excerpt from the task analysis “Rail Traffic Controller”.

As a next step, typical user groups of the electronic interlocking system were identified, and personas were created. Personas are fictive representative users of the new system (Cooper, 2008). By using personas, the needs and idiosyncrasies of typical users can be more easily reflected in the designing phase of the new system interface by the designer. It turned out during this step that the success of the design of a user interface of any future interlocking system will strongly depend on two factors. On the one hand, the success will depend on the degree to which the system covers the needs of an aging workforce of German railways. On the other hand, it will depend on the degree to which it covers the next rail traffic controller generation of "digital natives", who have expertise in- and affinity to the field of modern communication technology.

The preliminary body of work consisting of task analysis and user identification was the basis of the subsequent development of design ideas, concepts and sketches of possible system improvements. These graphically documented concepts were discussed with potential users of the system over and over again in order to find out further adjustments that have to be implemented in the next phase of redesign. These steps of feedback and subsequent redesign were repeated several times, to guarantee an ongoing progress of improvement in the design of the interface concepts (Fig. 4).

Finally, using an advanced, digitalized version of the prototypical user interface, structured interviews were conducted with experts in the fields of railway operations, usability engineering and industrial design in order to make a last revision of the prototype. The previously developed concepts and representative sequences of operations (which were defined during the task analysis in the beginning of the project) were incorporated in the final prototype to demonstrate its basic functionality.

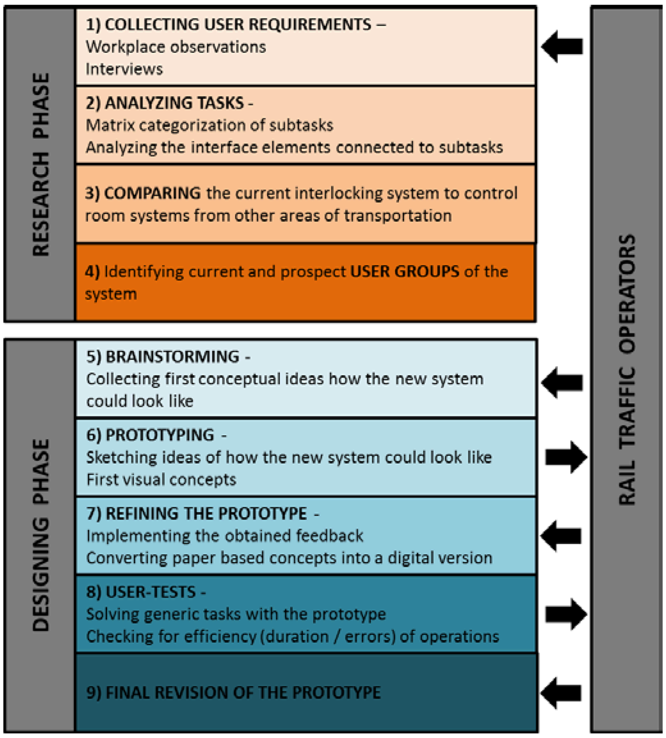

Fig. 4. Stepwise development of the new human interface concept

4. RESULTS AND CONCLUSION

In the following section excerpts of the multifaceted ideas to optimize the user interface of the electronic interlocking system are presented. All of these ideas were developed in close collaboration with professional rail traffic controllers.

A proposal regularly made by rail traffic controllers is to enable touch interaction as a new form of controlling the system. Touch interaction is not meant to replace mouse control, but it should be implemented as an alternative to it. Operations should ideally take place on one single high-resolution screen, suitable for multi-touch interaction. The control via touchscreen is not only a modern and by now established way of Human-Computer-Interaction. It can also be considered as homage to the advantages of the older electro-mechanic interlocking systems. In these older systems, operations could be made through a direct interaction with the object in the track control panel, by pushing buttons. Direct operations on objects you wish to interact with correspond to a natural mapping (the relationship between controls, their movements and the results in the world) according to the usability guidelines as defined by Norman (2002).

For the composition of train routes within the system, two different possibilities were considered. First, it should be possible to execute an entrance-exit control by the sequence of first selecting the train’s starting signal on the touch screen, then touching the target signal and finally confirming the route with touching an optically highlighted processing button. Second, an alternative that could be advantageous especially in the process of shunting with its numerous changes of tracks and direction is the ability to retrace a complex train route on the track control diagram with the index finger. This can be done to create a preview that can be processed subsequently.

A major innovation of the system is the abandonment of the convention of a systematic dichotomy between different forms of representing the tracks on the human machine interface. Usually, on the interface of German electronic interlocking systems there is a distinction made between a general overview of the entire area under the operators responsibility and specific detail windows, where most of the operations have to be controlled in. During the second and third design phase of designing the new interface concept, a growing consensus arose to make an effort to design the system in a way that all control operations can be made in a single topological representation of the track area. This central overview of the route network has to extend the entire region for which a rail traffic controller is responsible and it must be visible permanently.
Furthermore, occupied blocks in the track overview will no longer be solely indicated by a red illumination of the line representing the block. In addition to the illumination of the block, the train occupying the block will be clearly highlighted as an object. In this way the trains with their individual numbers can be noticed more easily (Fig. 5).

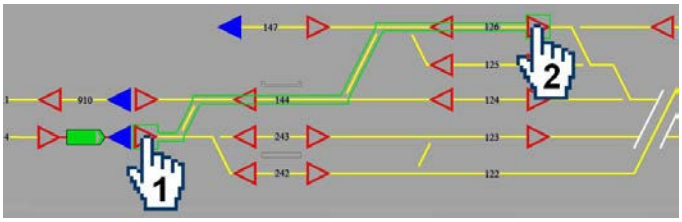

Fig. 5. Composition of train routes in the track overview by (1) selecting a starting- and (2) a target signal. After confirming and processing, the track will be represented by a continuous green line, with a train standing in front of the starting signal.

A further new approach in the system at hand is to reduce the number of required means of communication of the rail traffic controller. At the moment there are many devices available for communication, such as an analogue train radio connection, a radio connection for the train stations as well as GSM-R in independent systems. In the future, only a single headset should be provided that serves for all kinds of voice communication. In addition to that, the telecommunication window of the current interface, which appears rather overloaded, has to be replaced in favour of an innovative and more user friendly communication system. To contact a train driver with the new system, the corresponding train just has to be tapped on in the track control overview area. This opens a context menu that contains the option "call". By tapping on *call* the connection with the train driver will be built up immediately. This integrated communication system has the advantage that no abstract digits have to be looked up and dialed any more. This is just one example of how the electronic interlocking system could benefit from a direct touch interaction at the level of the displayed operational elements.

Certain general considerations have to be made concerning the intuitiveness of operations within the menus of a future system. Especially the ongoing effort to integrate more and more subsystems from different safety integrity levels and other workplaces into the responsibility of the rail traffic controller lead to special requirements that have to be met. The next electronic interlocking system has to ensure usability by harmonizing the human machine interfaces of all subsystems that will be integrated. From a user centred perspective, this is a necessary precondition for efficient and safe operations. A mixture of different styles of menu navigation, (e.g. explorer-like tree structures merged with link-structures and windows with different levels depicted by an index card logic) lead to an inconsistency in operation and should be avoided. Inconsistencies impair the predictability of the system for the user and lead to a reduced usability (DIN EN ISO 9241-110, 2004). For this reason, a *desktop solution* with icons and objects that open up windows was chosen for the new concept of the electronic interlocking system. This solution was consequently assigned to all subsystems to guarantee for consistency. If you define intuitive interaction as "an effective interaction that is associated with the unconscious application of prior knowledge by the user into a new context" (Naumann, Pohlmeyer, Hußlein, Kindsmüller, Mohs, & Israel, 2008), the advantage of prior cross-domain knowledge of people interacting with the new electronic interlocking system should also be properly made use of. The implementation of the desktop metaphor, well known from the majority of operation systems running on private computers appears useful in this context. Due to the high familiarity with these operation systems, the knowledge and routines obtained during the use of one system can be easily transferred to the new operational context.
In a main menu of the new electronic interlocking system the essential functions and subsystems can be found and started. Subsequently they will appear as windows on the desktop if you select them. These windows can be enlarged, reduced or closed both by touch gestures as well as through tapping well-known symbols located at the upper corner of the window. Additionally, the new system concept provides a task menu bar which is located at the border of the entire screen. It serves as an overview of all subsystems that are active in the foreground as well as minimized subsystems (in the background). All subsystems will be represented by symbols in the menu bar and can be selected from it quickly to pop up to the front again if they are needed.

A particular challenge in the development of the new system is to link it with other external systems that have not been integrated yet, for example the maintenance and service system used to dissolve disturbances in rail traffic operations. In the future operating system, the flow of dialogues between all integrated subsystems, (especially in the case of disturbances) should be significantly streamlined. Task sequences that typically occur in a sequential fashion in different subsystems will not be located in different subsystems anymore; they systematically have to follow one another. If one task of a common sequence of tasks is finished, the user will be automatically lead to the next task necessary to deal with in the chain of subtasks. This idea follows the principle of proximity-compatibility (Wickens & Hollands, 1999). This human factors principle states that if a task has a high "process proximity", meaning that certain subtasks always occur after each other, this task also requires a high "display proximity", meaning that the interface elements needed for these subtasks should be displayed close to each other, spatially as well as temporally.

In summary, future design activities concerning the electronic interlocking systems, usability and human factors should be particularly regarded. This is due to the ongoing changes of the demands that the rail traffic controller is facing because of technological progress and increasing responsibility due to railway system automation. It is therefore strongly recommended to consider especially the knowledge of human's perceptual processes, -capacities, and -limitations in future system design. Additionally, general principles of usability engineering, as they have been partially presented in this article should be regarded. The incorporation of human factors knowledge in railway systems development should be supported in order to contribute to user-friendly, safe and smooth running rail traffic operations of tomorrow.

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