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Towards a distributed cognition perspective of the Swedish train traffic system

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In Sweden, train traffic on the operational level is dependent on two main actors: train traffic controllers and train drivers. Train traffic controllers are engaged in a remote control process, monitoring train paths, points, and signals and when necessary, reschedule the current traffic plan with respect to perturbations and disruptions. The remote control process includes two different time frames which in turn require two different ways of working: one in the form of planning ahead and the other in the form of acting directly on feedback from the monitoring system. The main task of the train drivers is to operate their trains by following signals and the current plan set by the traffic controllers. The importance of a well-functioning collaboration between train drivers and train traffic controllers has lately received interest in the Human Factors & Ergonomics (HF&E) research (e.g. Tschirner, Sandblad & Andersson, 2014). This has led to updated work strategies for the traffic controllers that can enable them to continuously re-plan the traffic by projecting the traffic situation instead of the previous strategy to identify and handle conflicts as they occur. The new strategy is called *control by re-planning* (Kauppi, Wikström, Sandblad, & Andersson, 2006) and Kauppi et al. describe that it supports the traffic controllers' need to plan ahead and works as an efficient tool for solving traffic conflicts.

In several studies about the train drivers work situation, their use of information and how information and its availability affect driver behaviour, it is revealed that train drivers suffer from a lack of information (Jansson, Olsson, & Erlandsson, 2006; Jansson, Olsson, & Kecklund, 2005). To obtain relevant information is described as the main challenge in the work role of a train driver and it is concluded that "…*the drivers sometimes found themselves driving in an informational vacuum*" (Jansson et al., 2005, p. 40). Accordingly, while train traffic controllers have access to information about the overall traffic situation, the drivers have to do with the limited information provided by their surroundings, i.e. the trackside signals, and the driver advisory system (DAS) that usually holds static information about speed, current position of the train, and the original time plan. As the traffic controllers get improved possibilities to re-plan the timetable when necessary to adapt it to the current traffic situation, the drivers are facing a more dynamic situation which forces them to plan their driving behaviour based on information that might be outdated. One example of this can be when the traffic controllers decide to lower the speed limit for a specific section of the tracks due to issues with the infrastructure. This will affect all drivers in the area and their possibility to reach the end station on time. However, the static information that the drivers have access to will not display changes in real-time and the driver will know of the change only when he reaches the section in which the permitted speed has been lowered. With earlier access to this information, the driver can adapt his driving behaviour and potentially arrive at the end station on time by adjusting (in this case increasing) the speed wherever the time-table and infrastructure allow it.

The new work strategy in terms of control by re-planning is based on the idea that there can be only one plan for the whole train traffic management system, and that this plan must be made available, at any time, for all actors in the system. If there are perturbations or delays, a new plan is immediately created by the train traffic controller and should be shared among all relevant actors. This metaphoric perspective of the operational train traffic management system is based on the idea that the task of running train traffic is an automatic control engineering task (Andersson, Sandblad, Tschirner & Jansson, 2015). Consequently, the train traffic management system is regarded as a closed loop system, assuming the work of traffic controllers to be a stable and predictable component regardless of the different time frames and the need for different actions. The improvements made are expected to be beneficial for the traffic controllers, but it is still a great deal of uncertainty as to the benefits for the train drivers. Moreover, it is also unclear to what extent the remote control process carried out by the train traffic controllers is consistent with the idea of train traffic management in terms of automatic control and closed control loops. The new work strategy has, so far, not provided a proper solution for realising a robust and efficient train traffic in Sweden. Whether this is due to the fact that the plans have not fully been put into practice, or whether the plans themselves are endangering an appropriate understanding of the conditions for efficient operative train traffic management is not yet possible to decide. In a research project called DIALOG, we challenge the idea of operative train traffic management as automatic control engineering and closed control loops, and instead we propose a perspective based on distributed cognition (Hutchins, 1995a). Generally, train traffic research has focused on either one of the two main roles of traffic controller and train driver. However, this diminishes the importance of a well-functioning collaboration and information sharing activities between these roles. Therefore, we propose that the complex socio-technical system of train traffic must include both traffic controllers and drivers. We argue that the train traffic in Sweden will not reach its full potential unless the two roles are viewed as interdependent parts of the same socio-technical system.

The call for a systems perspective is not new and the relevance of widening the unit of analysis to include not only individual workers but whole socio-technical systems has long been asked for in HF&E research (e.g. Wilson, 2000). When expanding the unit of analysis to include both humans, the multiple types of artefacts they use, and the interactions between all these entities, humans and their actions are understood within their context. In this way, it is easier to grasp and clarify the complexity of a dynamic environment and the effects the social and physical surroundings have on behaviour and performance.

There are several theoretical approaches available for studying work in natural settings and with the socio-technical system as the unit of analysis. However, the theoretical framework of distributed cognition (DCog) has been noted as one of the most pertinent theoretical approaches when it comes to the study of work and interactions between human and technology (Luff, Hindmarsh, & Heath, 2000; Rogers, 2012). DCog focuses on understanding the organisation of complex cognitive systems and proposes that cognition should be studied "in the wild" as it naturally unfolds (Hutchins, 1995a). The underlying principle of DCog is that human cognition is fundamentally distributed within the socio-technical environment and extended to the system level. A main concern is the way information is represented, transformed, and propagated in the performance of tasks in the cognitive system (Hutchins, 1995a). Thus, cognition and knowledge are not viewed as confined within the individual but extended to the system level. DCog has successfully been applied to a wide range of complex domains, such as for example aviation (Hutchins 1995b), and nuclear power plants (Mumaw, Roth, Vicente, & Burns 2000). However, the theoretical framework of DCog, as introduced by Hutchins (1995a), has previously not been applied to the train traffic system.

In the ongoing research project, we would like to explore the train traffic system from a DCog perspective to identify problems, possibilities, and challenges in the Swedish train traffic system. The overall aim of this is to investigate how cognitive processes unfold in the real-world settings of train driving and train traffic control. A secondary aim is to challenge the theoretical framework of DCog by applying it to the highly distributed system of train traffic (to the best of our knowledge, the Swedish train traffic system is more distributed than the previous domains in which DCog has been applied). The work in this project will be done with cognitive ethnography as the basis for data collection. This is not a specific technique or method for analysis but rather a collection of techniques such as interviews, observations, and video recordings (Hollan, Hutchins, & Kirsh, 2000). With an understanding of the functional properties of this socio-technical system, we will build knowledge about the community of practice and reveal how cognitive activities are accomplished in these complex real-world settings of train driving and train traffic control. An application of DCog, and allowing the boundaries of what constitutes cognition to expand into the systems perspective, offers a new toolset for identifying both potential problems as well as opportunities for improvement of the human based work within the train traffic domain.

The ongoing research project embarks on a new perspective of the train traffic domain and will, contrary to prior research on traffic control and train driving, emphasise the collaborative nature of the work and highlight the fact that an understanding of both these roles and their interdependence is essential for realising a successful train traffic. Due to the complexity of the train traffic system, we consider DCog to be a suitable framework that will pave the way for a discussion about the benefits of a systems perspective in Rail Human Factors research. It is our belief that DCog, with its focus on information flow, will offer insights into the challenges related to the collaboration between the highly distributed train drivers and the traffic controllers.

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