Applied Ergonomics 45 (2014) 462–470

Contents lists available at SciVerse ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Investigations into the skills of modern and traditional train driving

A. Naweed*

Department of Psychology, University of Sheffield, Western Bank, Sheffield S10 2TP, UK

A R T I C L E   I N F O

Article history:
Received 1 September 2012
Accepted 17 June 2013

Keywords:
Train driver performance
Cognitive engineering
Models of human performance

A B S T R A C T

Rail operations are housed inside a complex and extremely dynamic system where work is distributed in time and space. The train driver has traditionally relied on their own decisions, plans, and actions to navigate the rail environment, but the use of modern driver systems that force how these activities are regulated has altered this dynamic. This paper reports the findings of a study that set out to investigate the skills of modern (enhanced display-based) and traditional (real world) train driving. Data were collected from a variety of UK domain experts ($n = 45$) using an innovative methodology that converged multiple techniques for knowledge elicitation and analysis. The findings are represented in a model of dynamic train control and discussed according to the specific features and nature of tracking skill in the rail domain. The utility of the model is demonstrated through work of its application to the design of a train simulator and research tool for systematic study of rail human factor issues.

1. Introduction

The natural train-driving environment is complex, unpredictable, and highly dynamic. Collision avoidance in this type of environment is influenced by a range of human factors issues and information processing limitations associated with sustaining attention for extended periods (Wickens and Carswell, 2007). Traditional train navigation requires the driver to process information sources held outside the cab (e.g., signals, speeds, landmarks) and apply a detailed body of route knowledge (acquired from experience). This allows the driver to connect their location with the upcoming destinations and optimise speed-error. In the traditional driver-cab, basic indicators such as a speedometer and braking gauges are used to fathom train state and carry out decision-making. Although train drivers only control the speed and acceleration of the train, train driving cognition is strategic, purposive (i.e., goal-directed), and quasi-mathematical (i.e., underpinned by mental time-distance estimations) (Branton, 1979). Whilst rail industries the world over still employ legacy systems dating back to the mid-20th century (including those in 'developed' countries), the last two decades have bore witness to a rapid growth in railway technology, and whilst train driving fundamentally remains unidirectional, emerging technologies are beginning to alter how train drivers correct speed-error, derive information, and correspond with their environment.

Today, train technologies are designed around signal awareness (e.g., Automatic Warning System; McLeod et al., 2005), train protection (e.g., Train Protection Warning System; Fenner, 2002) and 'supervisory' control (e.g., Automatic Train Protection; Simpson, 1994). These systems and approaches have introduced increasing layers of autonomous control in the train. For example, the Automatic Train Protection system calculates braking distances and applies automatic brake applications if the train is likely to violate movement authority (i.e., line speeds and stop signals). In the more advanced rail networks, drivers use enhanced information displays to operate. These displays, held in the driver–cab interface, advise train operation by previewing the route and speed trajectories (e.g., Einhorn et al., 2005; Howlett and Pudney, 2000; Kitto and Groves, 2011). Some of these technologies, such as Energymeiser (pictured Fig. 1a) aim to inform decision-making. In this system, a speed trajectory is calculated based on upcoming speeds, changes to the terrain, expected fuel use, and estimated arrival times. However, control is not forced or overridden by the system, and the driver is effectively left to operate using traditional driving principles, but under the guidance of a display that presents "what-if" scenarios. Thus, the driver may elect to follow the optimal trajectory (depicted horizontally) and influence how conservatively it is calculated (using soft-keys to increase or decrease estimated arrival times), and whilst some movement authority is shown (i.e., line speeds), signals are still located outside the cab.

Other systems migrate the signalling and movement authorities into the cab, and adopt a driver-train dynamic that relegates more control to the machine. For example, the European Train Control System (ETCS, pictured in Fig. 1b) previews the route but also

* Central Queensland University, Appleton Institute, 44 Greenhill Rd, Wayville, SA 5034, Australia. Tel.: +61 8 8378 4520; fax: +61 8 8378 4532.
E-mail address: anjum.naweed@cqu.edu.au.

0003-6870/$ – see front matter © 2013 Elsevier Ltd and The Ergonomics Society. All rights reserved.
http://dx.doi.org/10.1016/j.apergo.2013.06.006

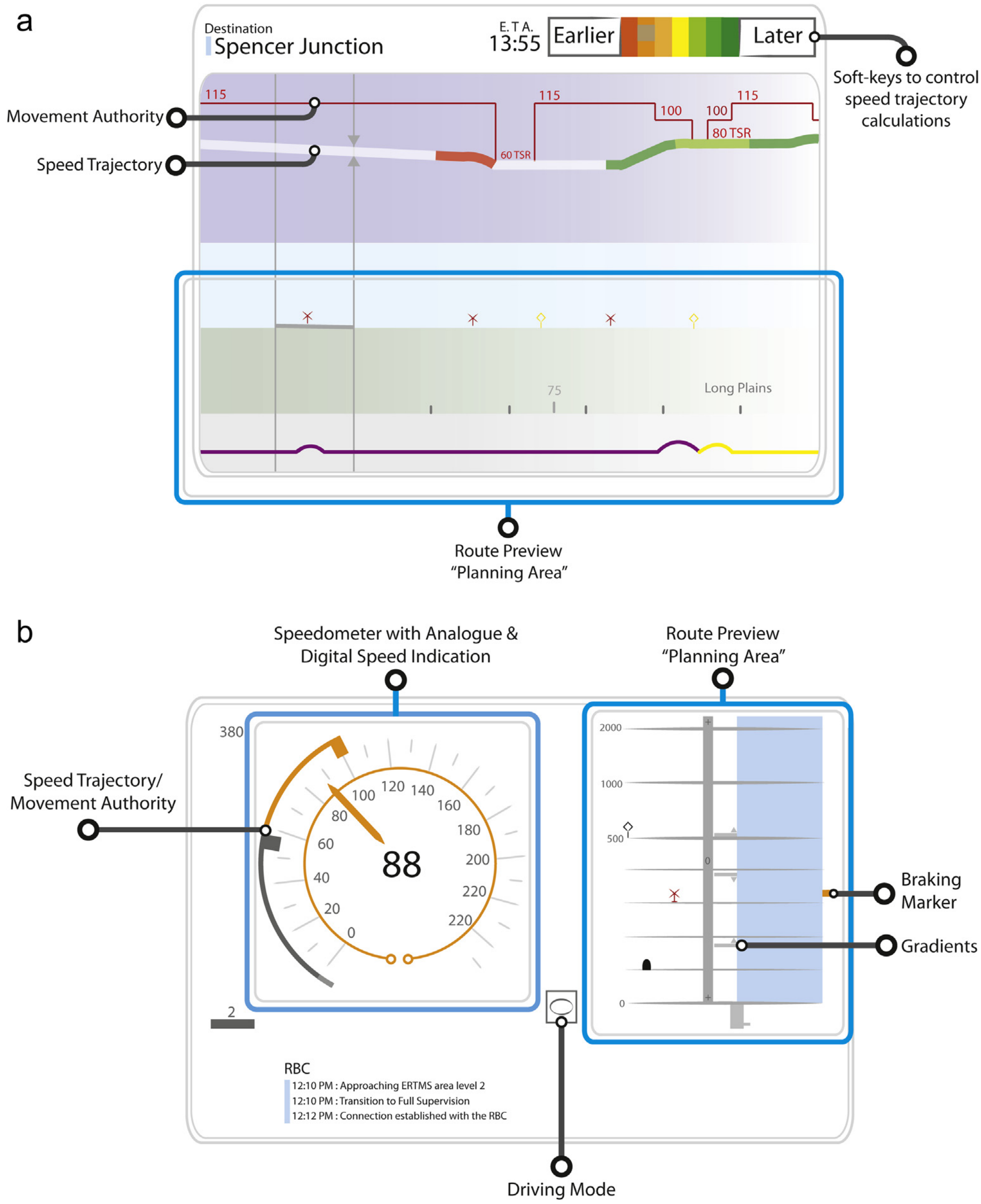

Fig. 1. Schematic of the displays in the (a) Energymeiser system, and the (b) European Train Control System with callouts depicting how the speed trajectory, movement authority and planning areas have been integrated into the train driving task.

parameterises (i.e., enforces) how train movement is to be regulated by the human. Upcoming route features are displayed in a planning area along with a feature that instructs the time to brake, and the system applies automatic throttle/braking if speed deviates from these prescribed limits (CENELEC, 2005). In ETCS, the speed trajectory is also displayed around the outside (i.e., perimeter) of the speedometer. These are all important distinctions as the resulting driver-train dynamic operates within an observable margin that has an upper (max) and lower (min) boundary, which the needle of the speedometer should be kept within at all times. Thus, train driving is underpinned by a system that monitors what the train driver does and if system parameters are violated, driver control is overridden to return speed within the predefined boundaries. This type of system does not aim to cater for "what-if" type decision-making, but rather, aims to instruct and enforce a scripted type of control. This driver-train dynamic is defined here as the 'modern' train-driving task, where an in-cab authority enforces how train movement and speed is regulated. In the case of the ETCS system, these are displayed to the driver with an enhanced information interface displaying a dynamic speed trajectory. Note that both the Energymeiser and ETCS systems are used in commercial intercity passenger and freight operations at the time of writing this paper.

Clearly, there are immediate and observable differences between Fig. 1a and b. For example, Energymeiser is horizontally oriented, whereas the ETCS system adopts a vertical orientation (i.e., towards direction of travel). However, irrespective of the similarities and differences, both of these displays show that rail technology is fundamentally evolving along the lines of augmented reality. This is where specific domain features from the natural rail environment are being abstracted into the cab. One direction leading on from this is to better support the traditional driving task (à la Energymeiser), and the other, to hand one or more components of the task over to a machine authority (à la ETCS). Suffice it to