

Ergonomics methods for identifying sources and effects of bus driver distraction

Abstract

This paper examines the effects of driver distraction. Driver distraction represents a significant problem in the public transport sector. Various methods exist for investigating distraction; however, the majority is difficult to apply within the context of naturalistic bus driving. This article investigates the nature of bus driver distraction at a major Algerian public transport company, including the sources of distraction present, and their effects on driver performance through the application of a novel framework of ergonomics methods. The framework represents a novel approach for assessing distraction in a Real-world context. The findings suggest that there are a several sources of distraction that could potentially distract bus drivers while driving, including those that derive from the driving task itself and those that derive from the additional requirements associated with bus operation, such as passenger and ticketing-related distractions. Taxonomy of the sources of bus driver distraction identified is presented, along with a discussion of proposed countermeasures designed to remove the sources identified or mitigate their effects on driver performance. This study through technique SHERPA is an analysis of bus operation indicated that some distraction-induced errors could potentially be made by drivers who are engaging in distracting activities while driving the bus. These include critical safety errors, which have the potential to adversely affect bus driver performance and bus crash risk, and operational errors, which have the potential to reduce the efficiency of bus driver performance when undertaking bus operation tasks other than driving the bus.

Keywords: ergonomics applications, task analysis, bus driver distraction, operation tasks, conclusions

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S Keffane

Department of Psychology, University Setif, Algeria

Correspondence: S Keffane, PhD in Psychology, Researcher, Department of Psychology, University Setif, Setif, Algeria, Email keffane1967@yahoo.fr

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Introduction

Distraction is a complex, multifaceted phenomenon and, despite the immense research effort devoted to studying the concept over the past two decades, there is still much to understand about its mechanisms and its relationship with other aspects of human cognition and behaviour.¹ One aspect of distraction for which there is limited evidence is its relationship with driving errors.² The concept of driver distraction has been the focus of intense research attention. There exists a large and expanding body of research that has documented the myriad ways in which distraction can impact on driving performance and safety. These include reduced longitudinal^{3,4} and lateral control;⁵ reduced situation awareness;^{6,7} and impaired response times to roadway hazards.^{8,9} Moreover, these degradations have also been shown to translate into an increased risk of crash involvement, with estimates indicating that secondary task distraction is a contributing factor in up to 23% of crashes and near-crashes.¹⁰ In addition, a range of studies have observed that distracted drivers demonstrate degraded performance on a number of safety critical driving measures, including impairments in longitudinal^{3,4} and lateral control (e.g.^{5,11} a reduced awareness of surrounding traffic and events;⁶ an increased tendency to miss traffic signals and signs and increased response time to roadway events^{8,12} and a reduction in time spent checking instruments and mirrors.¹³ Although there has been a plethora of distraction-related research in recent years, the majority has focussed on the drivers of conventional passenger vehicle.^{14,15} A number of taxonomies will list distraction as the driving error, rather than as a causal factor.¹⁶⁻¹⁸ These taxonomies do not consider what the error type following the distraction episode is; thus, offering little insight into the nature of the errors associated with distracted driving.

According to these taxonomies, if a distracted driver were unable to stop at a red traffic signal, their failure to see the traffic signal following the distraction would not be captured; rather, the distraction itself would be listed as the error. Other taxonomies list distraction as a causal factor in driver errors, but do not indicate the mechanisms by which it contributes.^{19,20} Two recent studies that have examined the nature of errors made by drivers found evidence that distraction is one of several factors that contribute to drivers committing errors.^{21,22} In an in-depth examination of 474 crashes,²¹ found that a significant number of crossroads, lane departure and same direction crashes were the results of errors caused by the driver being distracted.²² This paper presents a case study application of a novel framework of ergonomics methods for identifying sources of bus driver distraction and assessing their effects on bus driver performance. As part of research undertaken for a major transport company in Algeria, the potential for bus drivers to be distracted while driving buses was investigated. Specifically, the research aimed to identify what sources of distraction bus drivers are exposed to while operating buses, what their potential impact on performance and safety is likely to be, and what can be done to minimize driver exposure to them. The aim of this paper is to present the findings derived from this research and to outline the methodology applied.

Driver distraction

Driver distraction is acknowledged internationally as a significant road safety concern.²³ Although many definitions exist²⁴ conceptualize driver distraction as a diversion of attention away from activities critical for safe driving towards a competing activity. It also contains the types of distraction (visual, cognitive, physical) associated with

each distraction source and information regarding the odds of being involved in a crash or near-crash associated with each source and the percentage of distraction-related crashes in which the source has been found to be a contributing factor. Researchers typically distinguish between a range of different types of distraction, namely visual, cognitive and physical (manual) distraction; all of which have been shown to have disparate effects on driving performance.^{11,25,26} A large and expanding body of research has found that engaging in distracting activities negatively affects driving performance in a range of ways, including reduced longitudinal^{27,28} and lateral control,^{11,12} reduced situation awareness;⁶ and impaired response times to roadway hazards.^{12,13} Distraction remains largely unexplored in a public transport context. In addition to conventional driving,²⁹ some research has focussed on distraction in the commercial transport sector, such as heavy goods vehicle³⁰ and truck driving.^{31,32} In the context of bus driving, in particular, very little research has been undertaken, and the majority has focussed on mobile phone use by bus drivers.³³ Although taxonomies of distraction sources have been developed for conventional driving,³⁴ to date there has been no attempt to ascertain what sources of distraction exist within the context of bus driving.

Ergonomics methods for identifying bus driver distraction

The ergonomics methods have been proposed for identifying sources of distraction and for assessing its effects on driver performance (see³⁵ for a critical review). For example, methods used previously for identifying sources of driver distraction include reviewing police crash databases,³⁶ using self-report questionnaires³⁷ and conducting naturalistic driving studies involving in-vehicle video recording.¹⁰ In the context of bus driving, applicable methods for identifying sources of bus driver distraction in a naturalistic setting are currently sparse. For example, naturalistic driving studies are difficult and expensive to set up and run, self-report data are flawed for many reasons,³⁸ and bus crash databases containing the level of detail required are rarely available.³⁹ The assessment of distraction in a bus-driving context therefore represents a significant challenge. Aside from presenting the findings derived from our case study on bus driver distraction, this paper presents a novel approach for assessing driver distraction in the real world where in-vehicle recording, simulation, and laboratory tests are not available. The methodology applied (presented in Figure 1) involved the application of various ergonomics methods in an integrated manner. Using ergonomics methods in an integrated manner is attractive several reasons, and has been used or recommended to study a range of ergonomics constructs, including workload,⁴⁰ human error,⁴¹ situation awareness⁴² and command and control.⁴³

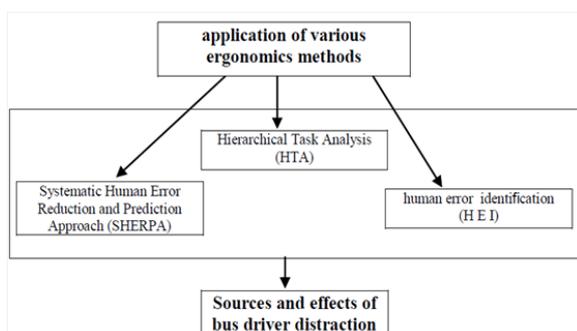


Figure 1 Ergonomics Applications for identification bus driver distraction.

The data obtained was analyzed using content analysis procedures to identify sources and effects of distraction) and informed the development of a Hierarchical Task Analysis (HTA)⁴⁴ of bus operation. HTA is used to describe systems in terms of the goals, sub-goals and physical and cognitive operations required to achieve them, including the goal-based human-machine interactions required during task performance. Describing the bus operation 'system' in this manner provides a description of the bus driving task that supports the identification of sources of driver distraction, since it offers a description of the operations associated with each goal underpinning bus operation, the interfaces or affects involved in the performance of each operation, and the physical and cognitive operations required. The contextual triggers of goals and operations are also described. The utility of HTA is also such that its outputs inform the conduct of further analyses, including human error identification,^{45,46} which was used in this case to assess the effects of distraction on bus driver performance. The HTA was used to inform the conduct of Systematic Human Error Reduction and Prediction Approach (SHERPA)⁴⁷ which involved predicting potential errors that might arise when the bus driver is distracted.

Materials and methods

Participants

Standard abbreviations Sample drivers were selected bus drivers employed by the transport company, a total number of samples involved in this study was 100, the aged 20–35 years (mean = 25.9, SD = 5.6) took part in the study. The driving experience between 02–10 years (mean = 5 years, SD = 5.6).

Materials and procedure

A video camera was used to record bus operation activities during the observational study component, and observational transcripts were constructed on-line using pen and paper. An HTA software tool was used to construct the HTA and undertake the SHERPA human error analysis. The HTA and SHERPA outputs were reproduced for presentation in this article using the Microsoft Visio drawing software package. The observational studies were undertaken naturalistically during standard bus operation, with the observers located in the passenger area of the bus near to the bus drivers. The information derived from the data collection activities was used to inform the development of an HTA of bus operation and to conduct a SHERPA human error analysis. A content analysis was performed on the data collected and the HTA to identify potential sources of distraction. To ensure validity, all analysis outputs were reviewed and refined where appropriate by an SME from the transport company.

Results

An extract of the HTA of bus operation is presented in Figure 1. Overall, seven key goal-based categories of tasks that the bus drivers currently perform while operating buses were identified. These were preparation tasks; physical vehicle control tasks; cognitive vehicle control tasks; route/timetabling tasks; passenger related tasks; communication tasks; and personal comfort tasks.⁴⁸ From the data collected during the focus groups, SME interviews, HTA and observational study, taxonomy of bus driver distraction sources was constructed. The taxonomy contains all potential sources of distraction that were identified during the study. The potential sources of distraction identified were categorized into seven main categories (Figure 2).

Human error identification analysis

Human Error Identification (HEI) techniques allow analysts to predict potential errors that might arise during a particular human-machine-interaction (HMI), working on the notion that an understanding of an employee’s work task and the characteristics of the technology being used allows us analysts to identify potential errors that may arise from the resulting interaction.⁴⁸ A distraction-based HEI analysis was conducted using the HTA of bus operation as its input. The SHERPA HEI method was used to predict potential errors that might arise when the bus driver is distracted. Of the various HEI methods available, SHERPA is the most popular and has the most supporting validation evidence, with recent application in aviation,⁴⁷ healthcare⁴⁶ and the military.⁴⁹ Each bottom-level task step from an HTA is first classified as one of the five SHERPA behaviour types (Action, Check, Information Retrieval, Information Communication, and Selection). Each the behaviour classification has a set of associated errors. The SHERPA error taxonomy is presented in Figure

Category	Source of distraction	Category	Source of distraction
 Technology	<ul style="list-style-type: none"> - Radio (V); - Radio handset (V); - Ticket machine (V); - Mobile phone (V); - Personal entertainment e.g. Ipad (V); - Passenger technology 	 Bus cabin	<ul style="list-style-type: none"> - Rattles (e.g. ticket machine); - Faulty sun visor; - Adjusting seat; - Adjusting seat belt; - Adjusting steering column; - Operating climate controls
 Operational	<ul style="list-style-type: none"> - Issuing tickets (V); - General broadcasts; - Personal broadcasts; - Recording broadcast details (V); - Communicating with Transport Operation Centre; - Timetable; - Reading route journal (V); - Amending route journal (V); - Changing route section points; - Bus stopping alert; - Hand brake warning alert; - Raising/lowering the bus (V); - Opening and closing the bus doors 	 Infrastructure	<ul style="list-style-type: none"> - Roadside advertising; - Lane width; - Road layout; - Road signage
 Passenger	<ul style="list-style-type: none"> - Passenger conversations; - Passenger enquiries; - Talking to passengers (V); - Unruly passengers; - Non-paying passengers; - School children; - Elderly & disabled passengers; - Passengers with infants; - Monitoring bus stops; - Assisting passengers (V); 	 Environmental	<ul style="list-style-type: none"> - Weather conditions e.g. glare
		 Personal	<ul style="list-style-type: none"> - Fatigue; - Incapacitation; - Sickness; - Medication; - Inexperience; - Eating; - Drinking

Figure 2 Sources of bus driver distraction identified.

Discussion

The findings suggest that bus driver distraction is a potentially significant road safety problem within the public transport sector. The risk of distraction is particularly significant in this domain where drivers are compelled, as part of their job, to perform additional secondary tasks over and above the primary task of driving the vehicle. These additional tasks are coupled with the fact that driving a bus is, by itself, a high workload task.^{50,51} As a consequence, bus drivers are not only regularly exposed to various distraction sources, but they may have less spare capacity than conventional drivers to attend to these distractions without compromising driving performance. Several sources of distraction that could potentially distract bus drivers while driving buses were identified. These include those that are present during conventional driving, such as eating, drinking and roadside advertisements, but also include an additional set of distraction sources that are present due to the requirements associated with bus operation, such as those deriving from interaction with passengers and ticketing machines. These distraction sources were classified into the following categories:

- a. Technology-related distractions;
- b. operational distractions;

3. The SHERPA error taxonomy and domain expertise are then used to identify, based on the analyst’s subjective judgment, any credible error modes for the task step in question. For each credible error identified, a description of the form that the error would take is provided and the analyst describes any consequences associated with the error and any error recovery steps that could be taken. Ratings of ordinal probability (Low, Medium or High) and criticality (Low, Medium or High) are then provided. The final step involves specifying any potential design remedies (i.e., how the interface or device might be modified to remove or reduce the chances of the error occurring) for each of the errors identified.⁴⁸ In order to identify the errors that could potentially arise when the driver is distracted, a modified SHERPA analysis was conducted. This involved taking each bottom level task step from the HTA and predicting the driver errors that might arise in the event of the driver being distracted, either physically, visually or cognitively, while performing the task in question.⁵⁰

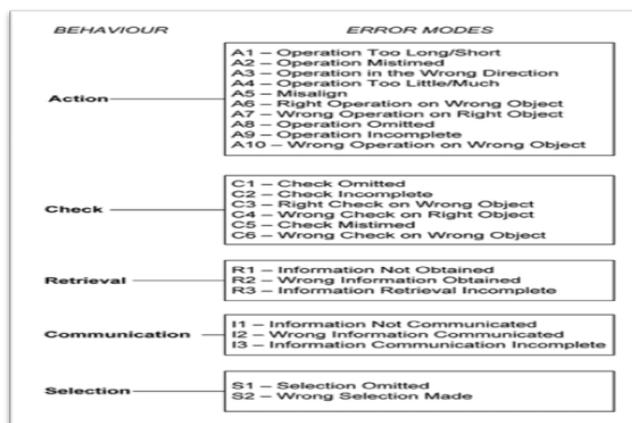


Figure 3 SHERPA error taxonomy.⁴⁶

- c. Passenger-related distractions;
- d. environmental distractions;
- e. bus cabin-related distractions;
- f. infrastructure-related distractions; and
- g. personal distractions.⁴⁸

Discuss three groups of distraction countermeasures:⁵²

- i. Data collection, legislation and enforcement, vehicle fleet management, and driver licensing;
- ii. Education and training; and
- iii. The vehicle, technology and road design.

However, before informed, appropriate countermeasures can be developed and implemented, it is clear that much further targeted research is required. The current study represents an initial exploratory study in this area, and while the findings are useful, further investigation is required. First, data on bus drivers’ exposure to different sources of distraction is required. While the present study has identified what these sources are in the bus-driving context, data on drivers’ exposure

to each of the different sources is not currently available. Beyond identifying sources of bus driver distraction, a contribution of this study has been the development of a novel framework of ergonomics methods that can be used to examine, in a real-world context, driver distraction in the public transport domain. Methods integration has been cited as a useful approach for studying a range of ergonomics constructs, and is particularly useful when multiple perspectives (e.g., both sources and effects of distraction in this case) on the data available are required. In this case the method was useful since it allowed analysts to describe the bus operation system (through HTA) in a manner that supported the identification of sources of distraction (HTA, supported by interviews, focus groups, documentation review, observation) and some of the anticipated effects of different distracters on driver performance (through SHERPA). As noted by,⁵² it is important to develop analytical tools that allow researchers to make a priori judgments about the likely effects of different sources of distraction on driving performance, given the considerable time and expense associated with more traditional impact assessment techniques. SHERPA is a promising tool for this purpose, and makes the important conceptual link between distraction and human error. Recent thinking and discussion about the mechanisms that appear to mediate the effects of distraction on driving performance⁵³ make it possible to further improve and validate the use of SHERPA as an analytical tool for the assessment of distraction. The approach presented here is a useful alternative when existing crash data is inadequate and there is little opportunity to undertake simulated or test track assessments of distraction.

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None.

Conflict of interest

The authors declare that there is no conflict of interest.

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