Towards an Intelligent Transport System

Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle–Highway Systems

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Edited by
ERTICO

Artech House
Boston • London

British Library Cataloguing in Publication data

ERTICO
Proceedings of the First World Congress
on Advanced Transport Telematics and
Intelligent Vehicle Highway Systems
I. Title
625.794

ISBN 0-89006-825-9

Library of Congress Cataloging-in-Publication Data

Proceedings of the first world congress on applications of transport
telematics and intelligent vehicle highway systems
p. c.
ISBN 0-89006-810-0, — ISBN 0-89006-825-9 (pbk.0
1. Intelligent Vehicle Highway Systems — Congresses.
2. Electronics in transportation — Congresses. 3. Mobile
communication systems — Congresses.
TE228.3.P76 94 94-37613
388.3'12 — dc20 CIP

Avenue Henri jaspar 113
1060 Brussels
Belgium

International Standard Book Number: 825-9-89006

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ERTICO	European Road Transport Telematics Implementation Coordination Organisation
ETNO	European Public Telecommunications Network Operators' Association
FERSI	European Forum of Road Safety Institutes
GMU	George Mason University
IBTTA	International Bridge, Tunnel and Turnpike Association
ITE	Institute of Transportation Engineers
IRU	International Road Transport Union
ITS AMERICA	Intelligent Transportation Society of America
IVHS CANADA	Intelligent Vehicle-Highway Society of Canada
OECD	Organisation for Economic Cooperation and Development
PROMETHEUS	Programme for European Traffic with Highest Efficiency and Unprecedented Safety
PTRC	Planning and Transport Research and Computation
SAE	Society of Automotive Engineers
TRB	Transportation Research Board
EBU	European Broadcasting Union
UITP	International Public Transport Union
US FHWA	United States Federal Highway Administration

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A PRELIMINARY SAFETY EVALUATION OF ROUTE GUIDANCE COMPARING DIFFERENT MMI CONCEPTS

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ABSTRACT

Little is known concerning the impacts of new information systems on road users' behaviour. In a field study two modes of a route guidance system have been compared with a conventional route map and a human copilot. Results of both systems usually lie between those for map and copilot. There were more navigation and orientation errors, and the routes driven were longer and took more time than under the copilot condition. Compared to the route map, however, both Man-Machine-Interaction (MMI-) concepts revealed their great potential and effectiveness in facilitating the orientation task.

1. INTRODUCTION

New road traffic information systems are expected to make important contributions to improving safety and efficiency of the road traffic system. Route guidance systems are at present very likely representing both the most prominent and marketable type of RTI (Road Traffic Informatics) developments. They are designed to assist the driver in route-planning and direction finding as well as to optimize routes within the road-network. In this context, investigating the impacts of the new systems on road users' behaviour is of crucial importance [1].

A field study on standardized test trials was carried out, where traffic conflict and error counting methods have been applied to analyze the safety and utiliy of a prototype route guidance system, which shall be on the market soon. Two different MMI-concepts were compared with conventional modes of route guidance. Results of this work are described in detail in [2] and [3].

The usefulness of route guidance should most clearly show up with the driver's decreasing knowledge of the area where he has to find his way in. The orientation task increases the mental workload of the driver and less cognitive resources are left for the guidance and control level of the driving task. The amount of increased task complexity and thus reduced traffic safety induced by the route finding task has been demonstrated recently in a study comparing the accident risk of residentials vs. strangers [5]. Strangers were significantly overrepresented in the causation of those accidents which happened in traffic situations involving orientation (e.g. in junctions, approaches to junctions, lane changes), whereas other causes of accidents (excessive speeding, tailgating) showed an equal distribution of accident causation proportion of strangers vs. residentials. Another study produced quite similar results analyzing safety effects of LISB (Leit- und Informationssystem Berlin) comparing error rates of drivers on routine trips and in unknown areas: solely that error types increased while driving on unfamiliar routes that could be traced back to orientation problems [3].

2. EXPERIMENTAL DESIGN

The experiment is a two factor square design with repetition of measurement on both factors. Subjects (n=16, 8 male, 8 female) were non-locals and not familiar with the road network of Munich where the test trials took place.

Experimental treatments:

1. A prototype route guidance system, giving visual and verbal information
2. A route guidance system giving verbal directions only
3. A "conventional" route guidance system (route map)
4. An "optimal" system (human co-pilot familiar with the area)

The prototype route guidance system is an autonomous system (i.e. there is no exchange of information with infrastructure) with static route guidance (i.e. identical route recommendations are made from the same source to the same destination). If the driver is not following the system's route recommendations, a new route is proposed from the vehicle's actual position, determined by means of GPS (Global Positioning System). The destination input by the driver is menu driven (see figure 1): a graph is shown on a display to define the traffic site for the next direction change; the distance to this point (in m) is digitally presented. A seperate window shows the length of the route (in km) to the choosen destination and the air-line distance. An additional feature of this system is an acoustical mode which supports the route recommendation on the display for instance by telling the driver: "turn left next junction". The volume of the speech output can be adjusted to the driver's needs. In the experimental treatment "acoustic mode" the route guidance system was exclusively based on these directions; the visual mode was turned off after the destination input.

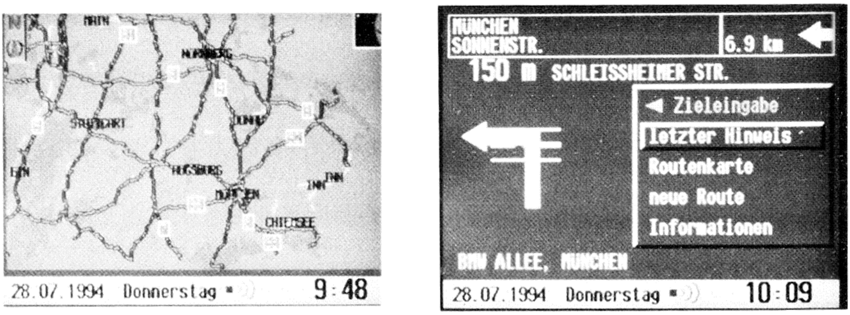

Figure 1 Area survey mode and route guidance mode of the prototype system

For the "route map" treatment the subjects had to use a commercially available map of Munich and its surroundings (where the field trials took place) with an alphabetical street directory. The subjects were free in their route finding strategies, i.e. they could behave as usual, write down intermediate destinations, outline their routes, ask people etc. In the "optimal treatment" condition, a human co-pilot gave all the relevant information as far as route guidance was concerned.

All test trials were conducted with the same two observers. Observer 1 (positioned aside the driver) recorded driver errors, critical situations and overreliance effects using an observation sheet, instructed the subjects and gave the standardized intermediate destinations. Observer 2 (positioned behind the driver) recorded distance and time driven, by mode of route guidance and type of test trial, and scored exposure measures such as frequency of blinker signals, lane changes and overtaking manoeuvres, number of situations where guarding was necessary, number of junctions and occurence of non-motorized road users. Furthermore, the observer operated the video camera recording system and acted as the human copilot (treatment 4). After the test trials the subjects had to answer a questionnaire about various aspects of the systems and their map reading abilities were tested by means of a paper and pencil test. Finally observer 1 scored the dangerousness of each recorded driver error on a rating scale (from 0 to 5).

The prerequisite for an effective application of behavioural and error data is both a precise definition of these incidents and an objective and reliable observation technique. In this context our working group has produced various techniques which have been applied in several field studies. The driver errors and critical incidents of this study were recorded using a classification of 80 errors (with respective exposure measures) in 8 groups [2]. Errors were defined as deviations from standards of correct behaviour (e.g. a missed turn). Each single error is attached to the traffic situation where the error occurred. For this purpose the respective traffic situations, for example characteristics of road segments and intersections, are indicated on the observation sheet; this is based on a frequently used taxonomy of traffic situations [3]. The potential of this reliability analysis is given by the equation: *number of errors = exposure to hazards x human error probability (HEP)*. To calculate error rates, the number of errors were related to their respective exposure measures.

Test trials

The choice of test routes and traffic situations with a degree of task complexity suitable to empirically evaluate navigation systems has been described in some detail [2, 3]. From this research medium task complexity is sufficient for non-local drivers in order to allow for "resource-limited conditions", i.e. task conditions where the driver has no spare mental capacity. Besides this general choice rule for the test routes' degree of complexity highly complex situations were deliberately included, as these might lead to overreliance and visual distraction. The test trials consisted of four different traffic environments (rural area, major city roads, residential area, inner-city area); each trial was subdivided into four parts with intermediate destinations.

3. RESULTS

Main results are shown in table 1. Analysis of variance indicated a significant influence of the mode of route guidance on the distances driven ($p < .01$) (column 1). A Scheffè-test, however, indicated that the difference in the means were significant for copilot and route map ($p < .05$) but not for the navigation systems. Under the copilot condition the subjects left their routes less often than under all other conditions.

Table 1

Distance and time driven and number of errors, by mode of route guidance

Experimental treatment	Distance (km)	Time (min)	Errors (abs)	Errors / min	Errors / km
Route map	59.9	211.6	180	0.85	3.02
Complete System	54.4	126.4	121	0.96	2.22
Acoustic System	56.8	130.4	106	0.81	1.87
Copilot	47.2	92.4	88	0.95	1.86

As far as the time driven is concerned (column 2) analysis of variance revealed a significant main effect by mode of route guidance ($p < .01$). Further analysis indicated that copilot, map and navigation systems differed from each other ($p < .05$) but not the acoustic mode from the „complete“ system. To some extent the distances driven are reflected by the time driven. The route map condition for instance produced long waiting periods due to route planning activities of the subjects and -above all- memorizing the route while driving and correcting navigation errors. The longer time driven under the navigation system conditions were primarily caused by programme errors. It happened that the subjects had to go out of their way in cases of route recommendations which would have brought forth traffic violations (yield turns, one-way signs, passing for residents only etc). Shorter travel times under the copilot condition can partly be traced back to a greater subjective safety felt by the subjects: they drove faster on all four trials. Column 3 shows the number of errors by mode of route guidance: significant differences were only between copilot and map condition ($p < .05$). Because each single error has its own respective exposure measure that influences the statistical outcome, the overall errors in this case were related to distance and time driven. However, in column 4 all differences have vanished; as far as the map condition is concerned this is obviously an artefact, because most of this "exposure-time" consisted of standing aside. The ratio between errors and distance driven as shown in column 5 is more informative. Analysis of the significant effects revealed that only the map condition differed from the copilot condition ($p < .05$).

Table 2
Selected errors by mode of route guidance

Experimental treatment	Right-of-way error rates (%)	Orientation errors (x)
Complete System	4.33	2.56
Route map	4.00	4.50
Acoustic System	2.40	2.25
Co-pilot	1.10	0.81

One example for reliability analysis are right-of-way violations in junctions (table 2). Analysis of the means (Scheffè-test) revealed that the complete route guidance system significantly differed from the copilot condition, what on the contrary holds not true for the acoustic mode. Further analysis of what led to the right-of-way violations showed three types of prevalent errors under the complete route guidance system's condition: red light errors, endangering pedestrians and cyclists, illegal turning ("overreliance effect"). These kinds of errors and further errors, not described in detail here (e.g. lane exceedences, wrong signalling), are likely typical visual distraction effects. Moreover, under the acoustic mode treatment reliability was not significantly different from the copilot condition. However, the visual information of the system showed its benefits especially in complex traffic sites. For example accessing signalized junctions on ring roads with multi-lane approach and several entries, the acoustic mode produced misleading informations for the subjects: The problem (e.g. which entry?) could have simply been solved by looking at the schematic representation of the junction on the display.

If the subjects got lost or turned wrong in junctions or entries, the category "navigation error" was coded in the observation sheet. In this respect, results for both route guidance systems again lie between those for map and copilot. In a further step, a category of "orientation errors" was defined, which included the navigation errors, mentioned above, and further errors related to the orientation task (e.g. discrepancy between signs and actions: blinker signal to the left but turning right). Means by mode of route guidance are indicated in table 2, which shows three groups differing significantly from each other ($p < .001$): orientation errors were more frequent under the route map condition than under all other treatments. On the contrary, under the copilot condition orientation errors were less frequent than under the two system conditions and the map. Finally, „good“ and „bad“ drivers under the map condition did not significantly differ from each other under copilot and systems' conditions as far as their error frequency was concerned. Thus, bad map readers gain most by electronic route guidance.

Another part of data analysis tried to compare the different modes of route guidance by estimating the dangerousness of the errors (67 dangerous events were recorded). Again the system conditions lie between map and copilot. A remarkable result can be found regarding the type of the test trial: in the residential area (23 events) and inner-city area (21 events) most dangerous events happened. They included more traffic situations with higher task complexity than the rural area and the area with mainly major roads.

4. DISCUSSION

Copilot

The copilot treatment was investigated as a standard to "optimal" route guidance. This was because: 1. A copilot is able to communicate with the driver 2. a copilot is capable of giving route recommendations in a timely manner 3. a copilot can use landmarks to help the driver identifying relevant spots of the road network 4. a copilot is not restricted to giving navigational aids, but can assist the driver on the manoeuvring level of the driving task as well.

This study indicates a human copilot -familiar with the road network- is an optimal route guidance "system": there were fewer errors (overall and specific), fewer orientation and navigation problems and the routes driven were shorter, and took less time than under all other treatments. Moreover, there were fewer dangerous events, too. These results are stressed by the answers of the subjects to the questionnaire where they expressed that the copilot treatment ranked first as far as criteria such as safety and usefulness were concerned.

Route map

This treatment could be labelled as the "worst-case" condition of route guidance. There were more errors, more critical events, the longest routes, and the lowest reliability. One remarkable fact is that most interindividual differences were brought forth in this kind of treatment. Supposed the route finding in unknown areas is usually done by means of route maps, then the increased accident risk of strangers is understandable.

Route guidance systems

Finally, attention should be focussed on the safety related effects of navigation. Usually under normal driving conditions ("data-limited case", i.e. if spare capacity is available) the order of importance of information is as follows: Highest priority for information about the road (control level), medium priority for information about the interaction with other vehicles (manoeuvring level) and lowest priority for navigation information (strategic level) [6]. But what happens if a driver cannot avoid a state of mental overload? It is often assumed that drivers are capable of ignoring less critical driving tasks (in terms of safety) to cope with overload conditions. Thus, differences in mental load as a result of navigation are expected to exhibit themselves in tasks like driving speed usage. No effects are expected on the occurrence of critical incidents. However, this is an optimistic point of view. It could also be argued that drivers under overload conditions are liable to change the usual prioritization of information, and that the usual order of importance breaks down. If navigational information is given priority over important aspects of the roadway ahead, then critical situations will occur. This kind of prioritization of the navigation task can be strengthened by overreliance effects induced by the system.

As this study has revealed, results for both route guidance systems usually lie between those for map and copilot. In general, the routes driven were longer and took more time than under the copilot condition. Compared to the route map, however, both MMI-concepts revealed their great potential and effectiveness in facilitating the orientation task. This is highlighted by the fact that worst-case and best-case drivers under the map condition did not significantly differ from each other under copilot and systems' conditions. From this it can be assumed that "bad" map drivers gain most by using an electronical navigation system. If the programme features are updated and based more on infrastructure information, then the reliability of the driver-vehicle system could be expected to be as high as under the copilot condition. Even now, the overall error rates, related to the same exposure measures such as distance and time driven, show no difference to the copilot condition.

Improvements have to be made with respect to driver errors at intersections due to overreliance and visual distraction effects, navigation and orientation errors by giving route recommendations timely and correct. Moreover, the driver-vehicle-interface design has to be improved in order to overcome problems of special driving tasks. This is demonstrated clearly by comparing both MMI concepts: verbal directions do as well as the combined visual and verbal version. Vice versa, displaying optical information did not generally improve navigation. Nearly all subjects spoke highly of the acoustic mode, which indeed was their primary source for route information, while the display simply was a supplementary source. Although, some improvements have to be made in the acoustic mode as well: route recommendations should be given timely (shortly before or at the point at which the driver is expected to react upon them); a clearer voice and proper spelling is desirable.

Especially with regard to route finding and driving in unknown areas, which is more dangerous, provokes more errors and more accidents, this study could demonstrate clearly the benefits of electronic route guidance systems in terms of safety and utility.

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