Investigating In-car Safety Services on the Motorway: The Role of Screen Size

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Abstract
Today's in-car information systems are undergoing an evolution towards device miniaturization as well as to real-time telematics services. In a road study with 26 participants, we investigated whether small smartphone-sized screens are recommendable for the communication of realtime safety services. We did not find strong overall differences between large and small screen setups in any of our investigated measures. However, when no audio was presented, safety services presentation on small screens resulted in significantly more long glances to the HMI than on large screen. Also, subjective comprehensibility of driving recommendations was best when screen size was large and audio presentation was available. Implications and further research opportunities are discussed.

Keywords
User studies; Telematics; Form factor; Design; Experimentation; Human Factors; Screen Size; Safety

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces—GUI;

General Terms
Design, Experimentation, Human Factors.

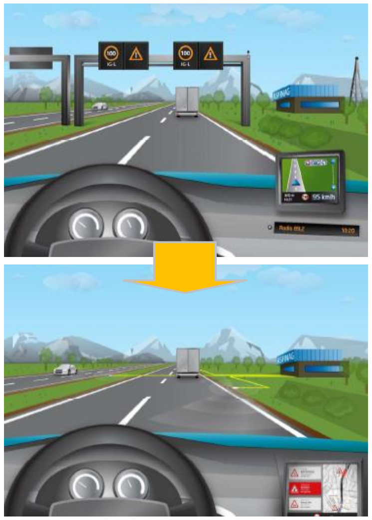

Figure 1. Top: current situation (information is distributed to road and in-car HMI). Bottom: ASFINAG vision of future V2I safety systems (all information is provided by the in-car HMI).

Figure 2. Large screen setup (top) and small screen setup (bottom).

Introduction

Intelligent Transportation Systems (ITS) are becoming widely used by drivers. Information on an in-car human-machine interface (HMI) is by far not any more restricted to providing navigation instructions, but increasingly includes safety information, such as dynamic speed limitation, or changes of the recommended route due to reported congestions. In addition, qualitatively new services are targeted, such as urgent incident warnings, dynamic roadwork information, or lane utilization. They are increasingly supported by advanced vehicle-to-infrastructure (V2I) systems which connect vehicles on the motorway to the road infrastructure via continuous bidirectional wireless communication [4]. The related vision that infrastructure providers and system integrators, such as the Austrian motorway operator ASFINAG, are currently realizing is to provide consistent realtime information to the in-car HMI, and to thereby make message signs on the road obsolete (see Figure 1).

Due to the increasing use of personal navigation devices and smart phones, the form factor of such systems has considerably decreased. There have been safety concerns in recent years related to small screen devices, which have been discussed in international consultation bodies. Based on results from survey studies ([6], p.34), a major conclusion was that the use of personal navigation devices does not have a significant negative impact on driving safety, as compared to no use of navigation devices.

However, so far most empirical research is focused on large screen sizes and simulator experiments. An interesting exception is a road experiment conducted by Lee [7], indicating that driving and navigation performance was better with a smartphone than with a large-screen device. However, this effect may have been caused by a significantly lower device position of the large screen.

In this paper, we report on a road-based field experiment to understand whether smartphones are recommendable as a means for presenting realtime safety information. We are especially interested in understanding the visual demand that may be imposed by the smaller screen and font sizes. The goal is to derive empirical guidance for the realization of motorway V2I safety services, which will presumably be rolled out in several European countries on a large scale within the next few years [4].

Method

Participants. The study was completed by 25 participants, receiving a voucher for a consumer electronics store as an incentive for participation. Participants were recruited via public announcements and the institute's test person database. Participants' age ranged between 20 and 60, whereas the mean age was 33.1. There were 13 male and 12 female participants. Experience with navigation systems varied between regular, sporadic and none (8, 11, and 6 participants, respectively).

Safety scenarios: Drivers were confronted with four safety scenarios: unexpected route change, speed limitation, lane utilization, and emergency stop. Participants drove along the motorway using a normal route following service, which was at a certain time interrupted to show the respective safety recommendation. To simulate the realtime character of a future V2I system, the time to react given by the

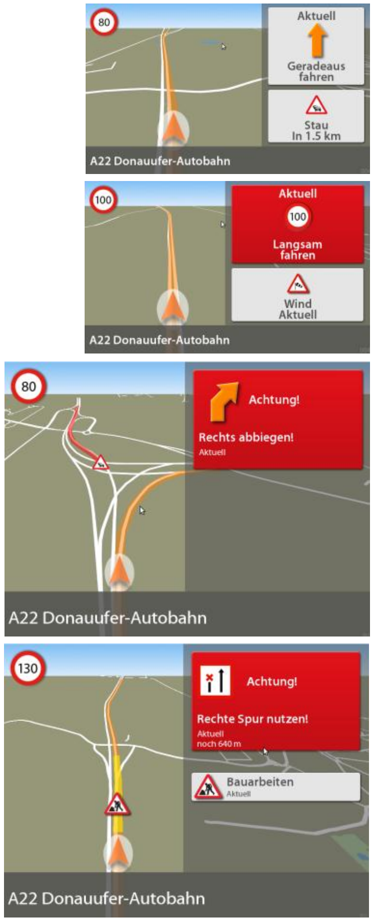

Figure 3. Example screenshots: from top to bottom: (1) small, normal route following, (2) small, speed limitation, (3) large, unexpected route change, (4) large, lane utilization

instruction relatively short on purpose: drivers were to change the lane within the next 200 meters, to change the route in the next 300 meters, and to make an emergency stop within the next 500 meters.

Visual presentation: The PC-based in-car application prototype (see a description of the system and its underlying prototyping platform in [1]) featured a split-screen design, which was based on a recently positively validated realtime safety information system [2]. The split-screen featured a bird's eye view map of the outside world on the left side and the messages boxes on the right side (see Figure 3). We had 1-3 message boxes with currently valid safety information and warnings at the bottom, and the resulting driving recommendations on the top (including icon and distance indications).

Screen setups: The 'large screen' setup consisted of a 12" screen, thereby representing a built-in driver information system (see Figure 2, bottom). The 'small screen' setup was a smartphone that was attached to the PC-based prototyping platform, using a custom video streaming module (Figure 2, top). Thus, we were able to display on the smartphone visualizations by the same rendering engine, conveying the impression of a fully functional smartphone application for the test driver. For both two screen sizes the same visual conceptual design was applied (see description above).

Auditory presentation: In order to understand the effect of presentation modality, half of the test drivers got audio instructions in addition to the visual presentations on the screen, and the other half only had to rely on the visual presentation.

When the safety instructions were presented by audio, the following speech information was subsequently provided (translated from German, example for unexpected route change): (1) an alert by an audible non-speech sound and verbally by "Attention!", (2) a distance indication "in 300m", (3) the driving recommendation "Turn right", and (4) the underlying safety information "due to a congestion". Such an audio message had a duration of about 4 – 5 seconds. The key information (2) and (3) was then repeated after 2 seconds.

Measures: The following measures were obtained, following the methodology outlined in [3]:

- Primary and secondary driving task performance: Directly after each critical situation, the experimenter provided a rating on a 7-point scale with regard to safe driving (no abrupt braking maneuvers, no drastic tempo changes, distance keeping) and the accuracy of complying with the safety recommendation.
- Eye glance behavior: Glances to the HMI were counted according to the following classification: 1) short glances of max. 0.5 seconds, 2) medium glances of 0.5 to 2 seconds, and 3) long glances of more than 2 seconds, following the methodology described in [3] and [5].
- Ease of comprehension: Participants were asked directly after the respective situation how comprehensible the presentation was to fulfill the HMI recommendations during the drive.

Experimental design: The study was a 2-factors (screen size *X* presentation modality) between-groups design. The participants were randomly assigned to each of the

Figure 4. Test route, with the following sections/phases: (I) training phase, (II) 3 main experiment phases, and (III) comparison phase (where the other UI styles were shown to the test participants)

two screen size setups, i.e. 13 persons got the large screen, and 12 persons the small screen. Each of these two groups was split into an audiovisual and a visual-only presentation sub-group.

Procedure and test route: During the test drives, the participants were accompanied by two researchers: an experimenter and an operator. The experimenter introduced into the test procedure, handed in the materials, and coded the driving behavior as described above. The operator managed the instrumentation and the system prototype.

In the briefing phase, participants were informed about the test procedure and signed consent forms, which were necessary due to special permits to stop in the motorway emergency lane. The participants then drove along a pre-defined route along several motorways in the Vienna metropolitan area (see Figure 4). The route was subdivided into sections for the training phase, three main experiment phases and a comparison phase. Each test drive was about 55 km, with an averaged test driving time of 45 – 60 minutes (thus summing up to 1500 km or 25 hours driving for the whole study).

The main experiment consisted of three phases in which each of the four safety recommendations was presented once. There was always a "normal" driving situation of approximately 4.5 km on average before a critical moment, in which a safety recommendation was presented. This way, natural driving was accommodated and a pure succession of unusual critical situations was avoided: the driver could "fall back" into a typical driving situation, and would then be confronted with a special safety situation.

Results

The presentation of the results is structured along the main measures: driving performance, visual distraction and ease of comprehension. For each of these, we analyzed main and interaction effects of screen size and presentation modality, based on 2-factorial ANOVAs. Error bars in graphs represent 95% confidence intervals.

Primary driving performance

The primary driving performance, as rated by the experimenter, was very high both for the large and the small screen (mean ratings of more than 6.5 on a 7 point rating scale). We did not find statistically significant effects of screen size and presentation modality on primary driving performance.

Secondary driving performance

Results for compliance with HMI recommendations provided a similar picture: mean ratings were at about 6.2 to 6.5 on a 7-point rating scale and also here we did not find a main effect of screen size. However, compliance with HMI recommendations was slightly higher in the audiovisual than in the visual-only conditions, if a 10% error probability level is accepted ($F=2.7$, $p=0.10$).

Visual distraction

Figure 5 shows the mean number of long glances per 10 seconds. One can very well see that if audio instructions were available, there were practically no long and dangerous glances on the HMI. However, in the visual-only conditions, the mean number of glances on the HMI was about 0.38 for large screens and 0.6 for small screens.

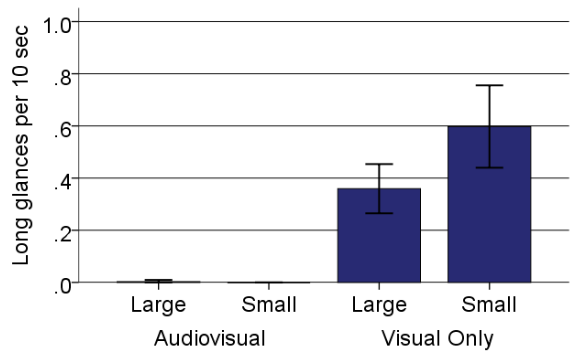

Figure 5. Mean number of long glances on the HMI per 10 seconds for large and small screen sizes (audiovisual and visual only).

We found a significant main effect of screen size and a highly significant main effect of presentation modality, F=6.0, p<.05, F=98.97, p<.001. Furthermore, a significant interaction effect between screen size and presentation modality was observed, F=6.34. p<0.5.

Perceived support

Figure 6 shows that the ease of comprehending the driving recommendations was rather high in general (6 and higher on a 7-point rating scale). While the ratings were rather homogeneous, it is clearly visible that the instructions were best comprehensible on a large screen with additional auditory instructions. Correspondingly, we found a significant main effect of screen size, F=5.97, p<0.5. While the main effect of presentation modality was not significant, the interaction between presentation modality and screen size was highly significant, F=7.03, p<0.1.

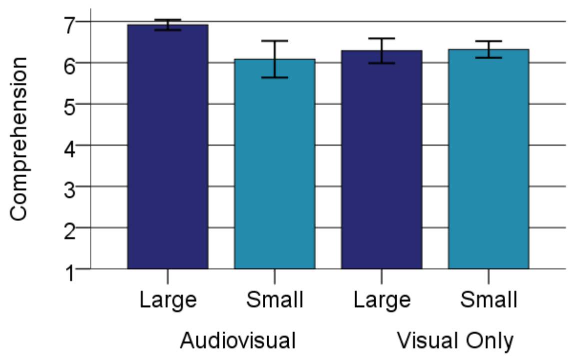

Figure 6. Ease of comprehending the driving recommendation of the respective UI presentation style (large vs. small screen, and audiovisual vs. visual-only).

Conclusions, Limitations, and Further Work

We can conclude from our experiment that the smartphone does not need to be excluded per se as a platform for presenting motorway-based safety services. Given a sound overall design concept, smart screens could even be realized with a similar layout and information density as large screen setups. Primary and secondary driving performance did not significantly suffer in neither of the experimental conditions. However, as the visual distraction results show, auditory presentation should be enabled when presenting safety information. This recommendation is especially important with smartphones, as potential problems with screen reading can be compensated by listening to spoken instructions.

Conducting more road experiments is recommendable, as these may offer a sort of ‘ground truth’ and could thus support the interpretation of numerous related simulator studies. Having said this, it is just as important to keep in mind the inherent limitations of road experiments. First, due to the significant management and conduction effort, a limited number of participants can usually be involved. Second, due to safety concerns, some constraints have to be imposed on participants' age and driving experience, as well as on the included driving conditions (test drives were only conducted at daytime and at days with unproblematic weather conditions). Furthermore, as our study was explicitly focused on the important scenario of motorway safety services, our findings may not simply be transferred to other environments and task types, such as navigation in the city.

Due to the strong impact of auditory presentation on distraction found in our study, we will investigate this aspect at larger scale and more systematically, by increasing the test sample and by including an audio-only test condition in the comparison. Furthermore, we are interested in understanding the specific requirements of the four safety scenarios investigated in the study. Potentially, small screens are less suitable for complex decisions involved in unexpected route changes than in simply reducing speed.

A further topic for further research is concerned with habituation and learning effects. Driving instructions, such as unexpected route changes or emergency stops, need to be accuracy followed, but they are not as often experienced as normal route following guidance. Thus, it is important to know when people get accommodated with such scenarios. Our study setup with three subsequent phases allows for such investigations. Regarding measurement methodology, we are currently investigating the 'driving calmness': preliminary tests during our road study indicate that a raised standard deviation of the gas pedal position may be a valid measure for identifying corrective actions and uneasiness.

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References

1. Baldauf, M., Schabus, D., Fuchs, M., Fröhlich, P., Suette, S. (2011).The ROADSAFE Toolkit: Rapid Prototyping for Road-Testing Novel Automotive User Interfaces. Adj. Proc. AutomotiveUI 2011.
2. COOPERS (2010). D16-IR 8200/8500: Final report for disseminating the demonstration achievements, revised business development & roll out strategy.
3. Fröhlich, P., Baldauf, M., Hagen, M., Suette, S., Schabus, D., Kun, A. L. (2011). Investigating Safety Services on the Motorway: The Role of Realistic Visualization. Proc. AutomotiveUI 2011.
4. European Commission. ITS Action Plan. 2010.
5. Jensen, B. S., Skov, M. B., Thiruravichandran, N. 2010. Studying Driver Attention and Behaviour for Three Configurations of GPS Navigation in Real Traffic Driving. Pro. CHI 2010.
6. Nomadic Device Forum Final Report, 2009, available at: http://www.esafetysupport.org
7. Lee, W.C., Effects of using a portable navigation system in real driving, Doctoral thesis, Yunlin University of Science & Technology, China, 2011.