Content Matters: Towards Handling E-Mail while Driving Safely

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ABSTRACT

Advancements in information and communication technology make new IT-based services in the tertiary scope of a car driver (short: automotive services) possible like e-mail and social networking and are highly demanded by customers. However, if not well designed, these services have a potential to dangerously distract drivers from their main driving task and therefore increase the risk of road accidents. Hence, we studied the effects of an in-car e-mail client on drivers' distraction. A low fidelity driving simulator was used to test 32 participants on their degree of distraction while driving. In this paper we present the findings of this evaluation. Our results show that when designing complex automotive services like an e-mail client one of the crucial factors besides the user interface is to keep the provided content simple and well structured thus reducing the amount of driver's distraction considerably.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation (e.g. HCI)**]: User interfaces, interaction styles, prototyping, voice I/O

D.2.2 [**Software Engineering**]: Design Tools and Techniques – user interfaces

General Terms

Design, Experimentation, Human Factors

Keywords

Automotive service, driver distraction, voice control, automotive user interfaces, lane change task, prototype, secondary task

1. INTRODUCTION

In the automotive industry mobile value-added services in the tertiary scope of a car driver – according to [12] hereafter referred to as automotive services – gain increasingly in importance. In addition to well known services like radio and navigation new services can also enable mobile working, browsing the internet or chatting with friends in social networks while driving.

Consequently, automotive services allow the driver to use their driving time more efficiently and effectively and thus enhance the driving experience. However, the proper design of such services is essential, because the driver must not be distracted by tertiary services from their primary task: driving the car [10].

According to a recent report of the Governors Highway Safety Association on distracted driving all types of distractions affect performance on tasks related to driving. Sources of distraction are countless and even thinking about something or talking to someone can be considered as forms of driver distraction [2]. This also applies to automotive services that are intended to improve the comfort and productivity of the driver by providing him or her with the ability to fulfill a secondary task while driving.

The research of Lee et al. [6] and Jamson et al. [3] already addressed the effects of speech-based in-car e-mail clients on drivers' distraction. Both, however, focused on distraction caused by the e-mail client itself. Lee et al. studied the effects of different user interface complexities on drivers' attention to the roadway, Jamson et al. compared a system controlled vs. a driver controlled e-mail system. Neither Lee et al. nor Jamson et al. included the structure and the complexity of the provided content into their research work.

In their literature review on in-car driver distraction conclude Young and Regan that not only the design of a device but also the complexity and emotionality of the secondary task influences the potential of non-driving tasks to distract drivers [11]. Therefore, developers and designers have to heavily focus on usability and intelligent content optimization. The user interface and the inner logic of the service have to be designed in a way that allows interaction with a service while driving without distracting the driver. The key requirement is: Make a useful function as simple and intuitively applicable as possible in order to cause as little additional distraction as possible.

During our research on the support of in-car mobile working we identified handling e-mails in a car while driving as a really challenging task. Furthermore, according to [1] one out of three young adults in Germany wants to have the ability to receive and compose e-mails in their cars. As handling e-mails in the car can be considered as a complex and time consuming task that is not possible while driving as of today, but is demanded by car drivers, we decided to investigate the effects of an in-car e-mail service on drivers' distraction in more depth.

2. MOBILEMAIL SERVICE

Object of evaluation was the service called "MobileMail" that has been developed at the Chair for Information Systems at the Technische Universität München. The service "MobileMail" is meant to foster mobile working in a car environment by making it

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possible for a driver to be up to date regarding his corporate or private e-mail inbox and accomplish simple actions in it.

"MobileMail" is a driver-controlled in-car e-mail client. Its main features include getting an overview of unread messages in a pre-configured e-mail inbox as well as more advanced features like composing new messages. All of these interactions used voice I/O and were user-paced. According to [4, 11] interaction via simple voice commands is less distracting and hence makes the usage of a service possible for a driver while driving a car without significant distraction. We used a predefined inbox thus simulating the positive effects of intelligent filtering and content aggregation.

One of the main characteristics of the "MobileMail" service was the voice-only manner of user interaction which eliminated the visual distraction component from the overall distraction. The operation of the service was solely carried out by using speech commands after having pressed a Push-To-Talk (PTT) button on the steering wheel. Voice-based interaction in MobileMail included commands for a full & a short overview of the e-mails and commands like "read message", "next", "back", "respond" and "send" for inbox navigation and simple message actions.

3. METHOD

3.1 Participants

32 randomly chosen participants from the Faculty of Informatics at the Technische Universität München participated in this study. As shown by Figure 1 the participants were almost evenly distributed regarding age and the annual mileage.

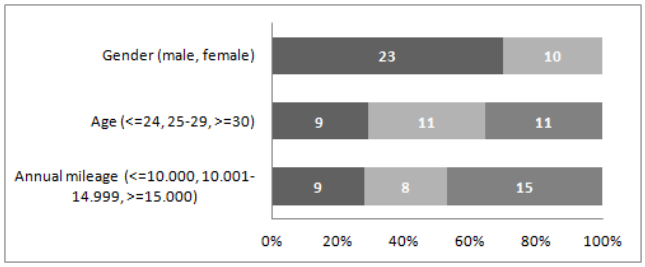

Figure 1: Gender, age and annual mileage distribution among participants

3.2 Apparatus

In order to have a robust experimental setting with repeatable driving tasks we used a low fidelity seat box equipped with a 27'' monitor, a Logitech® steering wheel with force feedback and pedals, standard speakers and a directional microphone. For measurement purposes the LCT software provided by Daimler AG has been used. The LCT approach has been chosen as it provided a good ratio in terms of costs, effort and validity of results [9].

Figure 2: Experiment setting

3.3 Stimuli

Measurement of attention, mental capacity and driver distraction requires test-drives in a simulator with driving as a primary task and several secondary tasks.

Even when reading e-mail at our desk on a PC or mobile phone and performing additional tasks like having a conversation or listening to radio, our cognitive load differs depending on several facts. On the one hand the length and the structure of an e-mail are crucial for the amount of information in the message we can perceive. On the other hand it is also the emotional factor that can influence our perception and reaction. E.g. an invitation to a weekly meeting is considered as daily business and is perceived less distractive than an e-mail from a relative.

So far there exists no common consensus on categorization of messages regarding the structural complexity and the emotional influence as these effects are highly dependent on the person and thus is very difficult to simulate. Therefore we focused on two extremes in terms of expected cognitive load when working with e-mails while driving. On the one hand we took an e-mail inbox with short and simply structured messages which content did not have any personal relation to the participants (see secondary task #1 and #2 below). On the other hand we simulated handling of complex messages implicating high cognitive load by using the so called digit span test (see secondary task #3 below).

The primary driving task consisted of the lane change task (LCT) in the above described setting. The simulated route was straight and consisted of 3 lanes with the overall route width of 3.85 meters. For each secondary task the participants were supposed to drive for 3.000 meters with the maximum speed of 60 km/h. Average time for track completion was 180 seconds. Per track the participants faced 18 lane change signs within intervals of 150 meters. In order to guarantee comparability and avoid learning effects all participants got same set of non-repeating tracks [7].

The secondary tasks were conducted as follows:

- *Sec. Task #1 (ST#1): Overview & navigation:* This task incorporated the use of the basic "MobileMail" functionality like getting a short overview of the inbox and navigating to a certain e-mail thus simulating handling of short and simply structured e-mails.
- *Sec. Task #2 (ST#2): Content retrieval and communication:* In the second secondary task participants were supposed to navigate to a specified e-mail, get it read by the system and answer the message with a context based response specified in advance by the study instructor. Thus we checked the ability of the participants to handle more complex facts within e-mails and to answer messages by interacting with the system.
- *Sec. Task #3 (ST#3): Digit Span Test:* This numbers memory test simulated high cognitive load on the participants and identified its influence on the driving behavior. Introduced by Miller 1956 [8], the digit span test determines the average ability of a human being to memorize up to seven words plus minus two and is widely used as a substitute for complex and emotional thoughts of human beings [5].

3.4 Design and procedure

After a short introduction to MobileMail and a short drive without a secondary task for determining the baseline, the participants performed the mentioned secondary tasks in separate runs. Goal

of ST#1 and ST#2 was to evaluate the influence of handling short and well structured content on the driving performance. ST#3 determined the influence of high cognitive load simulated by the memorization of auditory information on the primary driving task. Hereby the participants have been read different digit combinations by the study instructor that had to be repeated immediately by them. Seven rounds have been conducted starting with three digits and adding one digit every two rounds up to nine digits. Measurement data like apperception, reaction, maneuvers and track keeping of the participants has been recorded by the LCT software. All other data indicating attention and retention of the participants has been collected with a questionnaire after each task has been completed.

4. RESULTS

The results were based on the recordings of the LCT software and the evaluation of the questionnaires from the secondary tasks. The LCT recordings were used for calculation of the average deviation from the normative model and the standard deviation.

The questionnaires relating to the evaluation drives with the interaction of the "MobileMail" service (ST#1, ST#2) included questions on the structure and the content of the used e-mail inbox. In order to make the results quantifiable, points were assigned to each correctly answered question thus allowing us to make statements regarding the capacity of the short term memory of the participants as well as the correlation between the achieved points that indicated the cognitive load and the driving quality.

In order to analyze the influence of the secondary tasks (ST#1, ST#2 and ST#3) on the driving performance a paired t-test with a significance level of 5% has been used thus indicating whether significant differences in the data could be observed. Questionnaires were used for verification thus avoiding incorrect implications resulting from participants focusing only on the primary task. Influence of aspects like age, gender and annual mileage was verified by a correlation analysis.

According to the test setting the ST#1 had high auditory, low cognitive and low biomechanical distraction and thus showed the lowest deviation among participants, in average 10cm. ST#2 with high auditory, middle cognitive and low biomechanical distraction had ca. 13cm deviation in average. It wasn't surprising though that ST#3 with the highest cognitive distraction also showed the highest average deviation of ca. 22cm.

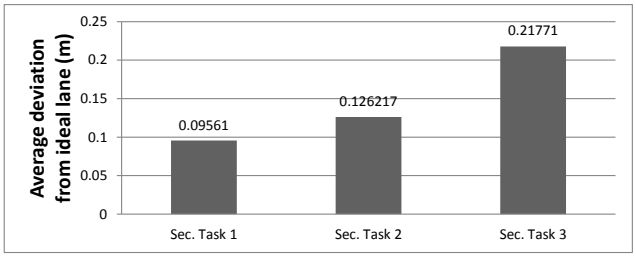

Figure 3: Average deviation from ideal lane

Based on these observations visualized in Figure 3 we can follow that the distraction of a driver when using the service "MobileMail" was significantly higher compared to the case when the driver's attention was focused exclusively on the primary driving task. This insight was not surprising for us as multitasking causes additional distraction [11].

Though, the far more interesting finding for us was that distraction in the case of handling simple and well-structured e-mails with a completely auditory interface was significantly lower than the distraction resulting from high cognitive load like in the case of the digit span test that can be compared with strong emotional or complex thoughts.

According to Table 1 the results indicated no significant differences between genders and no correlation regarding the annual mileage. Though drivers below 30 years had 5.1cm lower average deviation compared to the ones aged 30 and older. In this case the difference is significant and the implications are addressed in the discussion.

Group characteristic	Deviation ST#1	Deviation ST#2	Deviation ST#3	Overall deviation (m)
Male	0.09188	0.12185	0.20765	**0.42138**
Female	0.11688	0.12569	0.22313	**0.4657**
≤24	0.08357	0.11831	0.19198	**0.39387**
25-29	0.09009	0.1192	0.19651	**0.4058**
≥30	0.09634	0.12796	0.22731	**0.45161**
≤10.000km	0.09392	0.11998	0.22919	**0.44308**
10.001km-14.999km	0.09561	0.12627	0.21771	**0.43959**
≥15.000km	0.10071	0.131	0.22654	**0.45825**

Table 1: Deviations per group

For verification purposes we analyzed the achieved number of points in the questionnaires and the digit span test. According to Miller 1956 normally talented people can remember seven plus minus two aspects, thus if focused on a task at least 5 aspects. Performing the digit span test (ST#3) one can usually state that achieving 7 points in this setting and above can be seen as a normal human performance. By achieving 9 points like indicated below we even observed superior results.

Task	Average points achieved	Max. possible points
ST#1	5.91	8
ST#2	7.47	9
ST#3	9.06	14
Total	22.44	31

Table 2: Results questionnaires and the digit span test

Results in Table 1 indicate valid driving performance results as all the secondary tasks have been successfully accomplished by the participants and no negative correlation between the achieved amount of points and the recorded driving performance could be observed. Thus we can also imply that the cognitive performance of the participants was neither significantly influenced in a negative way by the primary driving task nor by the addressed secondary tasks.

5. DISCUSSION

As expected, our results confirm the fact that the complexity of a secondary task also increases the potential to negatively influence the driving performance. But, a far more interesting observation was that a secondary task that creates a cognitive load equal to complex thoughts of human beings (simulated by the digit span test in our case) [5] is significantly more distracting compared to handling e-mails with our automotive service "MobileMail".

So we can conclude that drivers can use an automotive service designed in a similar way to "MobileMail" without having an irresponsible risk of having an accident. This fact makes worth it to identify the relevant characteristics of this service. Besides the voice-based interaction in the experiment we also used a

predefined inbox as a result of intelligent filtering and content aggregation that contributed to these positive effects regarding the distraction.

Thus we can imply the following for the development of automotive services: Not only the user interface has to be designed in a way that makes interacting with a service simple and thus less distracting, but also the content of the e-mails provided by services similar to "MobileMail" must follow certain conventions. The content has to be simple and well structured like the content provided to the driver when interacting with the "MobileMail" service. Facing that, one has to gain a common understanding of how to categorize e-mails regarding their form and content simplicity. Several methods on quantitative text complexity analysis like Flesch-Kincaid Grade Level or Dale-Chall Readability Formula might be good candidates for approaching this topic and coming up with appropriate message filtering methods.

With our results we could also confirm the positive correlation between the age of the participants and their degree of distraction due to secondary tasks (see also [11]). Hence, in designing automotive services one has to take the users' age into account as older drivers are more prone to distraction when performing secondary tasks. Unfortunately this aspect hasn't been addressed yet in our research.

Though, our experiment has several limits that provide limited room for generalization. In our setting the results indicate no negative impact of the primary driving task on the mental capacity and therefore this effect has to be analyzed under real conditions. We used a low fidelity seat box in combination with the LCT test for measuring the distraction thus assuming that the participants show a behavior similar to real-road conditions. In addition to objective methods we will also involve subjective methods like NASA-TLX in the future research in order to evaluate user satisfaction and its correspondence to objective findings.

Furthermore we did not evaluate different user interface design guidelines against each other and did not compare distraction levels compared to common secondary tasks like radio usage. As we just focused on voice based I/O interactions we got no insights on the distraction level of other forms of content representation like the combination of visual and voice based output.

6. CONCLUSION & FUTURE WORK

In this paper we present the results of a simulator based study using the LCT test in order to evaluate the influence of executing secondary tasks with different cognitive loads on the driving performance. The performed study was conducted with 32 participants, giving our results a statistically substantiated base. This allowed us to draw justified conclusions on the evaluation and design of automotive services.

In this study we showed that in addition to the design of the user interface the content provided by an automotive service has also a great influence on the driver distraction. Therefore, the provided content has to fulfill certain requirements regarding structure and understandability. Detailed factors and characteristics will be addressed in our future research.

With respect to an in-car e-mail client we can imply that the service should not just provide access to all e-mails in the inbox as they are. It is crucial to detect complex e-mails and reduce their complexity before presenting them to the driver. Hence, further research on structuring appropriately the inbox of an in-car e-mail client as well as filtering and summarizing e-mails is necessary. For example with filtering and personalization the information overload of the driver can be reduced when he tries to find relevant information for satisfying his or her needs.

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