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Preface

Welcome Note from the Work in Progress and Interactive Demos Co-Chairs

It is with great pleasure that we have the opportunity to present the adjunct proceedings of the 2013 edition of the International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2013). Now in its fifth year, and building on the success of the previous conferences, this conference series is becoming the renowned international forum for the dissemination and exchange of theoretical and practical approaches in the field of automotive user interfaces, including novel in-vehicle services, new forms of feedback, issues related to workload and driver distraction, and approaches to improving driving performance.

For the WiP-poster and demo category we have received submissions from 10 countries (only first author's country used for reporting) including contributions from China and Korea. Many people have devoted considerable time in reviewing and selecting those pieces of work presented in this session. 23 reviewers completed nearly 40 reviews (2 reviews for most of the poster/demo abstracts, due to a very strict timeline, for some papers we received only 1 review; meta-reviews provided by the chairs). We could finally accept 17 work-in-progress posters and 2 contributions submitted to the interactive demo category. Contributions accepted for this category addressing topics such as gestural interaction, touch-screen UI's, intelligent vehicles, situation-adaptive UI's, UI's for E-vehicles, affective state detection, workload and danger correlation, cooperative guidance, driving simulator sickness, distraction management, tactile and speech feedback, and visual interface complexity.

This year, the poster and interactive demo session is being held on the second day of the main conference (October 29th, afternoon 2-4PM) at the main conference venue, Technische Universiteit Eindhoven. We expect that the poster and interactive demo session will be more alive than ever with these various new attempts and encourage you to come to the work-in-progress poster and interactive demo session and have fruitful discussions with researchers and practitioners from all over the world. Don't miss the ever-popular "one minute madness", where all poster/demo authors will be lined up for a rapid fire, 60-second opportunity to urge attendees to visit them and learn about their work during the reception. For the OMM, the poster session chair, Alexander Meschtscherjakov, will strictly enforce the one minute time limit for each presentation. We have heard that he has been hard at work devising an effective way to signal the end of a one minute time slot – we'll have to wait until the session to find out what he will choose in the end…

Last but not least we would like to thank each and every one of you for your valuable and continous support towards the success of this conference, especially for the work-in-progress poster and interactive demo session, and wish you a professionally rewarding and socially enjoyable stay in Eindhoven. Enjoy the conference!

PS: While in the Netherlands, don't miss to try out Boerenkoolstamppot met Rookworst ;-)

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Work-in-progress & Interactive Demos Co-Chair

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Workshops

EVIS 2013: 2nd Workshop on Electric Vehicle Information Systems

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ABSTRACT
Sustainability has become one of the key factors for car manufacturers worldwide. Electric mobility is clean, quiet, efficient and offers a great opportunity to keep our environment healthy. High effort has been put into new technologies, materials and infrastructure. Though, little research has been done on in-vehicle information systems (IVIS) to fit the needs of electric vehicle (EV) drivers. We argue that electric vehicle information systems (EVIS) are required to communicate EV specific information to all passengers in a positive and understandable way. This will be a key factor towards a better acceptance of EVs. With this workshop, we want to continue to bring together researchers, designers and practitioners of this design space in order to define a list of Grand Challenges of EVIS and work towards a bright future of EVs.

Categories and Subject Descriptors
H.5.2 [**Information Systems**]: User Interfaces – *Graphical User Interfaces, Input devices and strategies, User-centered design.*

Keywords
Electric Vehicle (EV), In-Vehicle Information Systems (IVIS), Electric Vehicle Information Systems (EVIS), E-Mobility, Workshop

1. INTRODUCTION
Range does not matter! Or, does it? A recent article in the New York Times [2] on a test ride with the Tesla Model S sedan and the detailed response by Tesla's CEO Elon Musk [7] showed that the confidence in the range of new electric vehicles (EVs) is still something to argue about. In this case, the test driver was not able to reach his destination despite Tesla's promoted maximum range of 300 miles. Should the manufacturer promise only realistic range numbers or should the driver be committed to follow exactly the suggested charging times and driving behavior?

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This dispute exemplarily shows the reasons for the concerns of potential customers: EVs have high prices compared to regular cars with combustion engines, but the range might not be sufficient for their driving habits, raising the question of a sufficient number of available charging stations.

Apart from these concerns, EVs also offer new opportunities. First, they are clean and quiet, giving the driver the chance to show that he cares for the environment and the people around him. At the same time, EVs offer a new driving experience, including a strong acceleration and recuperation, i.e. regaining energy while slowing down the car. Furthermore, some elements of the power trains are not needed in EVs, which offers more room and new design spaces [4], e.g. the center console, in the interior of the car.

We can conclude that EV drivers have different needs compared to drivers of regular cars. A lot of work has been concentrating on this issue concerning new battery technology or a growing charging infrastructure in larger cities. Nevertheless, we argue that a major factor of gaining the trust of the drivers and therefore raise the acceptance for electric mobility is the meaningful and understandable communication of the EV's information by customized electric vehicle information systems (EVIS). This important issue has surprisingly not been in the main focus of researchers.

However, first explorations have been made: e.g. Strömberg et al. [11] state that "information that help [the drivers] comprehend the relationship between [state of charge], [distance to empty], driving conditions and behavior are important in creating a mental model […] and can lead to that EVs are utilized in a more efficient way", but did not find a solution to convey this information in an understandable manner.

Outside of electric mobility, Tulusan et al. [13] analyzed eco-feedback [11] types for drivers and concluded that "most preferable were unobtrusive feedback systems, able to convey clear and contextual information" and that "not serving drivers' specific preferences and situated needs is a disadvantage that next generation feedback technologies should address".

Meschtscherjakov et al. [6] proposed five alternative pervasive feedback systems for regular cars. Included is the EcoPedal, a gas pedal trying to reduce fuel consumption by “pushing back against the driver’s foot when it detects wasteful acceleration”. However, “participants felt especially disturbed by systems with tactile and/or auditory feedback” [6].

The time is ripe to concentrate research on the special properties of EVs and the needs of the drivers. EVIS serve as the main communication channel between car and passengers and should therefore receive a suitable amount of attention by researchers and manufacturers. With this workshop, we want to continue to gather experts on the field and shift their attention towards the creation of meaningful and understandable EVIS.

2. AREAS OF INTEREST

The characteristics of electric vehicles are manifold and affect a wide range of different topics. To understand the requirements and needs of EV drivers, the following topics require special attention in the design and development process:

Driving Behavior. Driving EVs is different compared to regular cars with combustion engines. A strong acceleration without switching gears and regenerative breaking influence the driving experience. BMW proposes the “single-pedal control” related to their electric i3 Concept car. It allows driving with only the accelerator, regenerating energy when releasing the pedal, and lets the vehicle “coast without consuming power, driven by its own kinetic energy” [1].

Sound. When starting an EV, the familiar sound and movement of the engine are missing. Consequently, drivers have trouble knowing “whether the vehicle is ready to drive or not” which was confirmed in an experiment conducted by Strömberg and colleagues [11]. While driving, EVs are hardly hearable for outside traffic participants, which can be blessing in a quiet neighborhood but a curse for bicyclists or the visually impaired. Therefore, the U.S. Department of Transportation recently proposed minimum sound requirements for electric vehicles [8].

Range prediction. To communicate the available range to the driver, it might not be sufficient to know the State of Charge of the battery. Other factors such as current destination, weather conditions, the traffic situation, available charging stations or the current consumption of the infotainment system have a strong influence on range prediction. Lundström [5] identifies even more, such as the relevance of an energy source being private or public, which might affect the trust in the infrastructure.

Energy management. As energy is the limiting factor for electric vehicles, on board energy management becomes important to save resources in the case of a “last mile situation”. In this case, e.g. the air condition might take away resources for heating or cooling that would have been enough to allow a driver to reach its destination. Thus, intelligent controlling mechanisms are required and the driver needs to be informed why the AC stopped working.

E-Mobility Concepts. Not all EVs might be used in stereotypic usage scenarios like a three-person household with a garage. Novel mobility concepts such as car sharing or connecting vehicles to create a larger vehicle might affect how we see and use electric vehicles. EVIS are required to address the challenges of varying drivers that maybe never used an EV before [10].

3. OBJECTIVES & EXPECTED OUTCOME

In the first EVIS workshop [9], we identified characteristic properties of EVs, which have an influence on future interfaces and interactions (e.g. range and battery properties, safety of and trust in the new technology, user experience while interacting with EVIS, driving behavior of EVs, etc.) With this second workshop, we further extend the network of researchers, designers or practitioners of the design space. We invite participants to share their approaches to overcome the barriers that still keep the adoption of electric vehicles on a low level. We will work towards a meaningful research agenda, showing the Grand Challenges of EVIS.

With the help of this agenda, we hope to encourage the community to discuss the need to move away from simply adopting state of the art vehicles with combustion engines towards new EVIS concepts with their forms of interactions considering the special needs of EV drivers. The workshop will deal with but is not limited the following questions:

- What are properties of EVs that lead to the need of new interfaces and novel forms of interactions?
- Who are future EV drivers and what are their needs?
- How can we design EVIS to meet these needs?
- Which transportation concepts influence the design of EVIS?
- Do we need entirely new concepts for the interior of EVs or can we adopt regular combustion engine cars to meet the needs of EV drivers?
- How can we involve the other passengers in EV critical activities like trip planning and in-car interactions?

4. ORGANIZATION

4.1 Before the Workshop

The organizers will commit to publicize their workshop. The call for participation for this workshop will be distributed via related mailing lists as well as specialized ones (e.g. CHI announcement list, AUI list, TUM CREATE List) and will be distributed at several HCI- and E-Mobility related research groups and companies such as car manufacturers. We will use social media such as Facebook and Twitter as well to publicize the workshop. The website of the workshop will provide information about the workshop preparations, the CfP, and links to related material, so that people interested can become familiar with the scope of the subject and the goals of the workshop. Each submitted paper will be reviewed by at least two organizers. Authors will then get the chance to submit a revised version. Accepted position papers and other materials will be made available on the website in time before the workshop.

4.2 During the Workshop

Due to the experience of the first EVIS workshop at AutomotiveUI 2012, we expect about 15 participants. Therefore, we suggest a full day workshop that starts with an introduction to the topic followed by Pecha Kucha presentations[1] of the submitted papers. We chose this presentation method due to earlier experience in AUI workshops and think that presenting 20 images, each for 20 seconds, will give a valuable insight into the key ideas of the work presented. Hereby we avoid long and detailed presentations, foster compact presentations and leave enough room for discussions and group exercises. The presentations will be accompanied by discussions with the audience to clear details after presenting and interrupted by a coffee break. After a joined lunch, we will spend the afternoon with a first summary of what we so far know about the challenges of e-mobility and with the breakout sessions. These will focus on challenges discovered during the workshop and discuss different aspects of interacting with information systems of electric vehicles. Workshop participants will work together in small groups and finally present their ideas of how to encounter particular challenges. At the end we will discuss topics that remained open and encourage a get together for dinner after the workshop. Table 1 contains a detailed schedule for the workshop.

Time	Topic
09:00-09:15	Introduction
09:15-10:30	Pecha Kucha presentations (I)
10:30-11:00	Coffee Break
11:00-11:45	Pecha Kucha presentations (II)
11:45-12:30	Highlights, session grouping, preparation for break out session
12:30-13:30	Lunch
13:30-15:00	Break-out session
15:00-15:30	Coffee Break
15:30-16:30	Group discussions to define the Grand Challenges for EVIS
16:30-17:00	Wrap-up

Table 1. Proposed schedule for the one-day EVIS workshop

4.3 After the Workshop

A short report presenting impressions, pictures and first results will be published on the website shortly after the workshop. To retain the outcome of the workshop in a meaningful way, an overall whitepaper presenting the Grand Challenges of EVIS is envisaged to be published on the website as well. To frame the field of research towards EVIS, we envisage a publication of the submitted papers as a technical report.

5. THE PRESENTER

The organizers of this workshop form an interdisciplinary team with experts from Human Computer Interaction, Human Factors and automotive practice and research. Due to organizational reasons, the workshop itself will be presented by Sebastian Loehmann, who already ran the first EVIS workshop at AutomotiveUI 2012.

Sebastian Loehmann is a member of the HCI Group at the University of Munich as a PhD student and research assistant. He is involved in the interdisciplinary "CAR@TUM User Experience" project, which is a cooperation of BMW AG, Technische Universität Muenchen (TUM) and the University of Munich (LMU). The project focuses on the emotional aspects of e-mobility. Sebastian concentrates on the interaction with EVIS and explores the introduction of gestural interfaces into the automotive context.

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[1] http://www.pechakucha.org

Designing & Understanding the Impacts of Electric Vehicle Apps

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ABSTRACT
We are in the process of designing a series of apps for plugin electric vehicles (PEVs) with the goals of raising technology understanding and mitigating range anxiety. We targeted our apps at different moments in the user-car relationship: before, during and after driving. We are designing a study involving a number of PEV drivers to both assess their driving behavior over time, and to test our PEV apps. This paper presents our process and current status, for workshop discussion.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. See: http://www.acm.org/about/class/1998/

Keywords
Electric vehicles; range anxiety; Designing; App; Ambiguity; Study.

1. INTRODUCTION
In the plug-in electric vehicle (PEV) use context, range awareness, or lack thereof, may manifest itself through a phenomenon referred to as *range anxiety* [2, 7]. Range anxiety is the anxiety or fear of not reaching a location before the battery is empty, occurring while driving – or even prior to driving – as driver may worry about later planned trips. The main cause for this problem is that PEVs have a more limited driving range, e.g. Nissan Leaf has a claimed range of about 160 km (100 miles), in combination with charging times of approximately up to 8 hours in normal power plugs and up to 2 hours in fast charging stations for a fully charged battery. This is due to available battery technology and limitations of the electrical grid. This means that it might take hours to correct planning mistakes, or even make the driver stuck if discovered too late. While there is hope for improved battery technology in the future, e.g. using supercapacitors like graphene [3], current understanding does not offer viable solutions for improving battery performance.

Range anxiety is considered to be one of the biggest psychological barrier for the PEV, and studies show a need for more energy information and better user interfaces to provide better means of handling and avoiding these unnecessary situations [4]. It is not unusual that these problems occure because the drivers expect the PEVs to work in the same way a conventinal car works [8]. Indicating that the information system is forced into the conventions and designs of conventional cars, rather than having its own design.

However, the majority of the commercially available PEVs have their driving range above 80 km, which is twice, and in most case three to four times, the daily driving habits of the general public in Europe, USA and Australia [1], showing that the PEV is well adjusted to the needs of people if rare occasions (long trips) are excluded. On the other hand, this assumes that the PEV is fully charged every morning, something that is likely to fail from time to time, as things tend to happen. I.e., fuses break, people forget to plug in over night or over lunch, unexpected trips occur in the last moment, unexpected traffic jams requires more power to run air-conditioning or heating, charging stations are occupied or broken, there is a blackout in the area, the driving style or topography requires more power than expected and so on.

The objective of our position paper is to show the current status of our interaction design work in the PEV area, focused especially on addressing such contingencies. We will describe our design concepts, and the design sensitivities we developed during the process (especially the need for ambiguity as a counter-balance for contingency). We will also describe a study that we are preparing with drivers on the field and hope to discuss our study plan at the workshop.

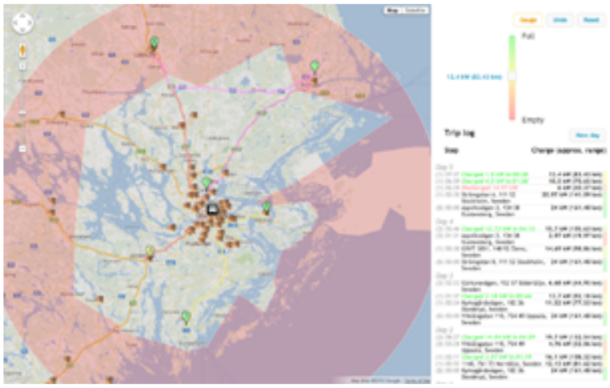
2. A series of apps
Our work is in large part driven from explorative stance, investigating possible futures using design methods.

In earlier work we have been trying to address range anxiety by exploring how distance-left-to-empty information could be visualized in more accurate and intuitive ways, using maps and parameters of the world [5].

This design concept represented the range as a polygon (which we later found is not original to us) and was used without an electric vehicle, by users who assessed, in interviews with us, *what it would be like* to own an EV, and the five respondents in our study reported that the prototype helped them understand the new technology. The design concept can be used also after driving to reflect how the EV has worked, and what were the effects of different factors like traffic jams, etc., during driving. However we have not yet tested the concept in these conditions as yet.

One reason we did not continue with the "range-in-all-directions" idea is that such interfaces need to make lots of map API calls which are increasingly restricted (by means of quotas) by the map API providers (e.g. Google maps).

Another concept we worked with focused on helping people make a decision whether to hire an electric car or a conventional gasoline car. A car hire operator that we cooperate with has indicated that the customers ask the (not unexpected) "will I make it to this destination" (and back) question, with its more elaborate version of driving "via" certain places. Our design provide the possibility for the customer to play with a number if via points in between the start and stop location (the rental station). When the customer plays with the route, the system provides a



Educational app.

Car rental app

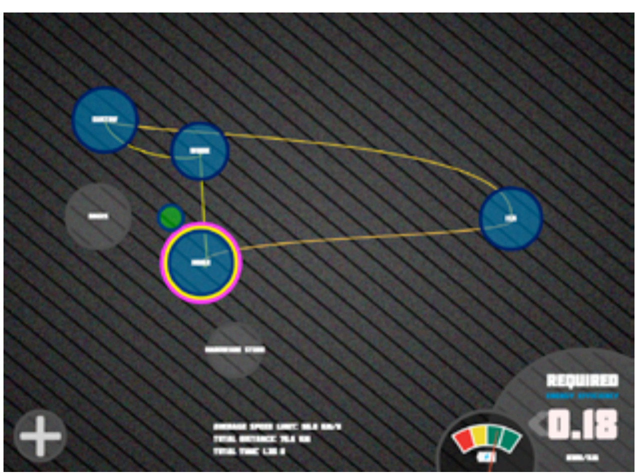
recommendation by giving an approximate degree of confidence (from "this route is easy", through "drive slow and you will make it", and all the way to "don't even think about it".

Since we cannot know exactly in advance how a trip will go, it is important to leave space for ambiguity in our design. We have thus decided to show the recommendation as part of a continuum, rather than a precise border (in range/not in range) as employed in our first prototype. Of course, the main difference is that we focus on a given trip rather than "trips in all directions" which is rarely a need, yet it is good for educating users about new technology.

Our app for driving aims to take into account the contingencies that one may face during driving and adapt its recommendation to the user depending on the energy left in the battery. This design is grounded in observations of different ways of coping with range problems among experienced PEV drivers [6]. One such coping strategy was to calculate the approximate *kWh per km* that one can use during driving in order to make it to a destination.

This design omits the map, yet it presents a quasi-geographical representation of several places that the user needs can select in a preferred sequence. During driving it detects "deviations from plan" in relation to the energy spent and helps the driver by e.g. decreasing the "target" kWh per km if too much energy was consumed.

Ambiguity is important in this case as well, since it is difficult to drive with a constant kWh/km, and this indicator, while useful, does not cover aspects such as future needs for heating/air



In-car app.

conditioning in a traffic jam, or future climbing slopes which should require building an energy reserve (thus driving with even higher kWh per km to be able to spare for the coming slope).

We are in the process of instrumenting this app with the on-board-diagnostic connections necessary to test the app during driving. As we will start driving around with this and other apps, we are certain that design improvements will be needed as well as new concept ideas will come about.

During our app design process, we came to see a parallel between driving an electric car on a proposed route with a given amount of energy and riding a bicycle on a proposed route, with the energy expenditure a certain human can usually exert. There are common aspects such as the importance of terrain elevation, as well as differences such as e.g. traffic jams. We are considering designing user interfaces for both cases in parallel and see how the two processes can feed into each other.

3. Design of a field study

Our current status is that we have recently got a grant for testing our designs and strategies in practice to verify the impacts that smart apps can have on driving practices and the understanding of range. We hope that the apps can provide better and quicker understanding of energy consumption, range and of how driving style affect these parameters.

Our current study design is a controlled study with half of the informants driving without (an elaborated version of) our driving app, and half of the informants driving with it. Our hypothesis is that drivers using our app use the PEVs to a higher extent and, as they understand and trust the technology more, dare to use the PEV for longer routes or on lower battery levels with less range anxiety.

In order to gather data during the study, but also for our app to work correctly, we have designed our own hardware platform that collect and transmit on-board diagnostic (OBD), as well as position (GPS) information, and uploads this to the cloud.

Data collection will be followed by reflective and contextual interviews with the informants.

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Identifying EV drivers' needs for information communication technology to ease the EV charging process

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ABSTRACT
Known barriers of Electric Vehicles (EVs) include their limited range and, to some extent, the underdeveloped charging infrastructure. This position paper presents initial results from a field study investigating the experience of EV drivers who are supported by a newly developed charging concept (ELVIIS) consisting of a web, smartphone and in-vehicle application. By connecting power grid owner with the telecom and vehicle industry such a solution can be achieved. Presented are the self-reported experiences of 11 EV drivers using Volvo C30 electric, captured via open-ended interviews after the completion of the trail. Highlighted are the user needs for information communication technology (ICT), in particular remote access. It should be noted that the ELVIIS charging concept is used in this position paper as an example to illustrate the need of ICT (e.g., remote access) rather than an evaluation of the overall ELVIIS concept. Further analysis will be performed to evaluate the concept in detail.

Categories and Subject Descriptors
H.5 [**Information interface and presentation**]

General Terms
Design, Human Factors,

Keywords
User experience, Human machine interaction, electric vehicle, information processing, automotive interface, decision making

1. INTRODUCTION
The ELectrical Vehicle Intelligent InfraStructure project (ELVIIS) is a cross-industry project with the goal to ease the charging process of electric vehicles (EVs) by means of Information Communication Technology (ICT), see [1-3, 19]. Two field-studies, in which drivers experienced EVs for one month each, investigated the value of driving EVs (Study 1) and the potential added value of information technology in EVs (Study 2). Reported are initial findings from the second field study (Study 2) performed in 2013, in which the proposed ELVIIS charging concept was tested. The field study focused on 3 aspects of the charging experience, (a) the consumer value of ELVIIS charging concept (i.e., benefits/sacrifices), (b) the experience of range anxiety, and (c) the Human-machine-interaction. In this position paper, initial findings related to the need for ICT are explored, rather than the overall evaluation of the ELVIIS concept.

1.1 The ELVIIS charging concept
The ELVIIS charging concept provides ICT support that enables EV drivers to use any outlet and automatically get the cost added to their own bill (Figure 1), see [1-3,17, 18]. It is hypothesised that the barrier for using private (e.g., a friend's) and public outlets can thus be decreased by providing the driver an easy way to pay for the electricity used (cf. [4-5]). It is also hypothesised that the uncertainty regarding the EV as a limited resource vehicle decreases by allowing drivers to access and control information related to the charging of the EV, via a web, smartphone and in-vehicle application (cf. [6-7]). More specifically, the mobile telecom network is used to coordinate the charging of vehicles, which increases the efficiency of the grid [18]. The driver decides when the car should be fully charged, the minimum range required to charge immediately, and the current to be used for the charge. The information is sent over the mobile network to a system that determines the best time for charging, based on the lowest cost and current demand on the grid. After that, the cost is added to the driver's bill, no matter which power outlet is used.

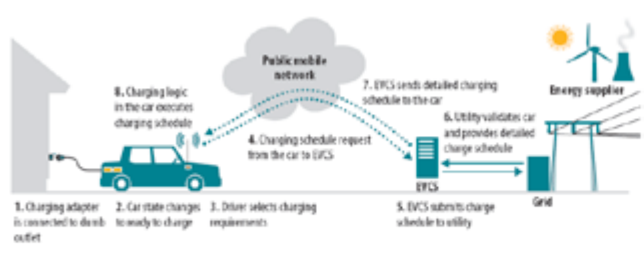

Figure 1. Overview of the ELVIIS concept, illustration inspired by illustration by Ericsson [18]. Step 3 illustrates the role of the driver. The EV driver interacts with the system in three ways: (1) via the in-vehicle application, (2) the web application, or (3) the smart-phone application.

As an EV driver you are typically aware of the range you need for a day. Imagine that you drive about 50 km á day, and you typically leave home roughly about the same time. The ELVIIS system then enables the EV driver to set up a charging schedule accordingly, that determines the minimum range (e.g., 50 km) and flexibility to the system; the vehicle is charged as fast as possible until the minimum range is reached - then starts charging according to the grid/personal preference on price/demand. The driver can change, update, or stop a charging schedule (remotely) when necessary (e.g., you need to leave earlier due to a re-scheduled meeting) via the smart-phone, the web or in-vehicle application, explained below.

1.1.1 In-vehicle application
The in-vehicle application (touch screen) can be used to adjust users' personal charge profile, minimum driving range that should be charged immediately, time for when the EV should aim to be fully charged by, and maximum charging current (cf. Figure 2).

Figure 2. Illustration of the in-vehicle system that the driver uses to adjust current charge settings.

1.1.2 Web application
In the web application, it is possible to view the EV's status of charge (SOC), estimated range and the charging schedule (cf. Figure 3). It is also possible to alter the user's personal charge profile, force the vehicle to start charging immediately, and to see statistics over previous charging, including the monthly charge reports. In addition, the users can see a map with their latest charging places as well as notifications issued by the system (e.g., the cord is disconnected).

Figure 3. Illustration of the web application. The driver can access information regarding charge history, billing information amongst other.

1.1.3 Smartphone application
The smartphone application provides similar functionality as the web application; it is possible to force the EV to start charging immediately and to view its SOC and estimated range as well as to receive notifications related to the charging. However it is not possible to see the charging history or monthly reports there.

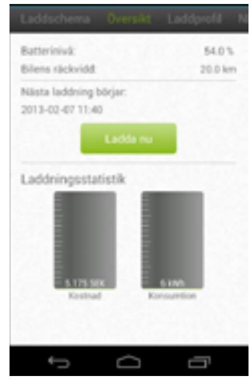

Figure 4. Illustration of the smart phone application. The user can access, via different tabs, charging schedule, and charge profile. The user can also decide to start the charging directly.

2. METHOD
2.1 Data collection
This study is based on the data from the second trail within the ELVIIS project (Study 2). Collected are the self-reported experiences of 11 EV drivers using the ELVIIS charging concept for one month in a Volvo C30 electric (a battery electric vehicle). The participants were given the task to use the EV as their main vehicle of the household. In total, 11 in-depth interviews were performed at the end of the EV trail period; 6 women and 5 men. The age ranged between 31 and 66 years. All had experience of participating in the previous one-month trail using EVs without having access to the ELVIIS charging concept. The follow-up session consisted of semi-structured interviews divided in two parts. Part 1: the drivers' perceptions and attitudes towards using the charging concept. This included open-ended questions regarding value creation together with the explanation model of critical incidents [8-9]. Part 2: the drivers' interaction with the EV. This included open-ended questions regarding the usability and functionality of the interface using probes in the format of reaction cards [10-11]. The reaction cards consisted of a list of adjectives, which can be used to describe user experiences of EVs. The lists consisted of 100 randomised adjectives (40% positive, 40% negative, 20% neutral). Each interview lasted for about 60 minutes.

2.2 Analysis
All interviews were transcribed using a third party. A qualitative assessment of the transcripts was performed in which a process of data reduction [12] and "open coding" were performed [13]. The identified citations were grouped and their meaning was analysed form the perspective of consumer value, the trade-off between the benefits and sacrifices perceived by the customers in the offering of a supplier [9,14, 16]. Furthermore, all material was analysed

from the perspective of distributed cognition [cf. 15] to identify the emergent properties of the interaction between the driver and the interface; thereby being able to differentiate the functionality, information provided and role of the interaction. The activity of interest was constrained by the decision: "I will/will not drive to destination A" and how that activity influenced the daily life of the participant.

3. RESULTS AND ANALYSIS

Presented is the initial analysis of identified value drivers (i.e., the first level of data reduction). Here, value is not constrained by the value of the physical product, but also the service and relational dimensions of value is considered (cf. [14, 16]). All material has been analysed and citations were grouped as either a benefit or sacrifice. Here, a benefit is considered to be something that would increase (positive driver) or decrease (negative driver) the value of the newly developed ELVIIS concept. The following sections present seven emergent themes ("needs") from the data of which 3 emerged from the list of "benefits" and 4 emerged from the list of "sacrifices": (1) Need of remote access (benefit), (2) need of information availability (benefit), (3) need of limited range control (benefit), (4) need of synchronisation (sacrifice), (5) need of feedback (sacrifice), (6) need of personalisation (sacrifice), and (7) need of integrated functionality (sacrifice).

In the following sections, the number in brackets after identified value driver shows the number of participants who expressed a certain statement.

3.1 Need of remote access

Most frequent benefits with the used ELVIIS charging concept are those opportunities that emerge by accessing information about the charging process remotely via the web and smartphone applications (e.g., receive notifications about the progress and interruptions of charging). Examples of value drivers/benefits within this category are as follows:

- Remote access to information (11)
- Accessibility (8)
- Ability to show others (3)
- Check charging progress (5)

3.2 Need of information availability

Another emergent theme is related to the fact that having access to information at multiple places open up for opportunities that ease the charging process. Examples of identified value drivers/benefits:

- Availability (9)
- Confirm settings (6)
- Feedback (3)
- Multiple access points (4)

3.3 Need of limited range control

Many of the identified benefits are related to the ability of the ELVIIS charging concept to address issues related to the limited range of the vehicle. Examples of value drivers/benefits are:

- Information to use as decision support (9)
- Control the charging process (6)
- Access to private/other outlets (5)

3.4 Need of synchronisation

The importance to show the same time-stamp as well as the same data was highlighted. Also, the information in these applications should be presented and visualised in the same way, e.g. the graphs should have same layout (i.e., provide familiarity). Some basic functionality should be available in all applications, e.g. one should be able to see details about the latest charge in all applications, but the full charging history may be available only via the web application. Examples of the value drivers that would increase the value of the proposed concept:

- Time (5)
- Data (6)
- Presentation (3)

3.5 Need of feedback

Many negative value drivers concerned a lack of feedback in terms of lack of usability and trust. Many participants actively looked for confirmation. It is for example highlighted that the applications need to confirm that a change is registered. Also, the concept should provide functions that enable feedback on driving style to be able to encourage the user to drive more "green" (e.g. inform the user how to drive to save energy). Examples of the value drivers that would increase the value of the proposed concept:

- Confirmation (8)
- Encouragement (4)

3.6 Need of personalisation

A need for personalisation was highlighted. Respondents expressed a need for setting own preferences regarding the content on the overview page. Also, it should be possible to set own preferences regarding the optimisation of the charging (e.g. if one wants to charge with "green" energy only then he/she could select this as the optimisation criteria). Examples of value drivers that would increase the value of the proposed concept:

- Own overview (3)
- Own charge optimisation (3).

3.7 Need of integrated functionality

Generally, the participants are satisfied with the functions available in the concept (given that these are error-free), but they would like to get access to more (integrated) functions. Examples of the value drivers that would increase the value of the proposed concept:

- Amperage control (8)
- Charging spots (7)
- Trip planning (6)

4. DISCUSSION AND CONCLUSION

The presented results highlight the need for extra support regarding the charging process of EV. By evaluating the benefits and sacrifices associated to the ELVIIS concept the initial analysis highlights 7 emergent themes that ease the experience of charging EVs. When participants compared their experiences when charging without support (Study 1) and charging with the support of ELVIIS, several participants (7) stated that charging with the developed ELVIIS charging concept was easier. Indeed, the results show that a great majority of the participants (9 of 11) stated that they would recommend the ELVIIS concept to a friend using an EV, or use it self in an EV. Interestingly, it is noted that the attributes of the information technology used (smartphone, web, in-vehicle application) for presenting the ELVIIS charging concept influence the experience of the concept (e.g., remote access). It is also noted that the charging experience extends time and space and the physical boundary of the vehicle itself. Further studies will evaluate the overall experience of the proposed concept and its possibilities for minimising known barriers of full-scale adoption of EVs.

5. ACKNOWLEDGMENTS

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Towards a Multisensory Representation of Electromobility Characteristics

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ABSTRACT
In this paper, we want to follow up the question, how characteristics of electromobility could be represented in the interior of electric vehicles (EV). For that purpose we followed a user-centered approach to collect intuitive and implicit relationships between some descriptive characters of electromobility and real materials. In a study with 13 participants multisensory 3-dimensional mood-boards representing the users' point of view were created. Participants were able to sense the materials and their structures and surfaces by vision, touch and smell. Results demonstrate an alternative approach to visualize the users' preferences for materials and show first impressions of users' associations with EVs. This can be used as an impulse for engineers and designers to fit the needs of future EV drivers when designing EV interiors.

Categories and Subject Descriptors
H.5.m [**Information Interfaces and Presentation**]: Miscellaneous

General Terms
Design, Experimentation

Keywords
Multisensory, Haptic, Materials, Aesthetic, Automotive, Electric Vehicle, User-Centered-Design

1. INTRODUCTION
Currently, the automotive industry finds itself in a sustainable structural period of transition [2]. The change of mobility has started. With it the future of mobility brings alternative fuels, lightweight constructions, driver automation and a smart vehicle, which is "always on" [10]. In the case of electric technology, this also leads to a different setup and design of the car itself [12]. Besides these novelties, the purpose of a car is perceived as more than getting from one location to another: It is a product with an emotional attraction expressing a certain kind of lifestyle [9], which is especially important for electromobility. But how do current car designs translate these modified requirements? On the one hand, customers should not be frightened with a too futuristic design. On the other hand – as the former BMW designer Chris Bangle said in a slightly provoking manner - most design teams tend not to disengage themselves from a well-known conventional design vocabulary [5]. Subsequently, in this paper we report on a new approach to augment the design of electric vehicle (EV) interiors by choosing materials which support the customers' view on electromobility (see Figure 1). We followed a user-centered design approach and tried to answer the question if there are associations in users' minds connected to electromobility and what they look like. Results show that most participants associate the term "sustainable" with a green artificial turf. Participants argued that turf is organic and a renewable resource. In contrast, the term "innovative" is mostly combined with soft polyvinyl chloride (PVC), because this material is fascinating and not common in every-day life.

AutomotiveUI'13, October 27–30, Eindhoven, The Netherlands. Adjunct Proceedings.

Figure 1: The collection of selectable materials

2. RELATED WORK
First of all, we will provide insights into user-centered design approaches, the usage of mood-boards and multisensory design.

To develop products with a high usability level, Gould and Lewis [4] introduced three fundamental principles. Next to an iterative procedure and an empirical concept verification by the user, they stressed the focus on users and tasks in early stages. To match needs and interests of users even better, Norman advocated a user-centered design philosophy in 1988 [15].

Participative design is an approach to support the active involvement of users in the research and design process. Participative design is part of a user centered design approach including methods such as design workshops, collages and creative toolkits. The findings can lead to inspirations for the design team or even design guidelines [13], [7].

Kansei Engineering focuses on the user as well. It translates the user's feeling into design specifications [14]. Thereby participants describe their desired product by adjectives. The so collected characteristics are translated into design parameters. This methodology should increase the chance to meet the user needs when launching a product. One important factor is that Kansei includes all senses [3]. The Kansei Engineering method can be used to capture ambiguous demands of users to design car interiors based on their associations [8].

To find out more about user requirements (e.g. opinions about a concept car´s interior quality), the user-clinic-method or car-clinic-method is applied in the automotive-industry [1]. With this method, car companies receive useful suggestions and user-associations to improve the product before launching.

Mood-boards or image-boards are well-known design tools to visualize mental connections. They help to capture the mood of the user group, provide a source for inspiration and are very important for developing a product-language, which users can understand [6]. Woelfel et al [21] used mood-boards as a visualization tool showing the mental connections of workshop-participants to a certain topic. Participants received 200 pictures and had to decide for only five of them to finally arrange a mood-board. Visualizing information with this approach was perceived as very helpful. Schmitt and Mangold [18] used a multisensory 3D-Model to understand the experiences of customers even better. Important for them was to use realistic stimuli addressing multiple senses.

Schifferstein and Cleiren [19] analyzed pros and cons of product experiences by comparing unimodal and multimodal information. One result was that multimodal stimulation seems to make the identification and evaluation of objects easier.

In this paper we report on our approach trying to combine parts of the above mentioned methods. It is our goal to visualize mental connections to a certain aspect – in this case electromobility – including not only the sense of vision but also of the touch and smell.

Figure 2: Participant arranging materials to a mood-board

3. CHARACTERISTICS OF E-MOBILITY

More than 20 studies and articles about electromobility were screened to find specific advantages or characteristics. E.g. Peters et al. [16] describe EVs as "...sustainable and energy-efficient means of transport". In the UC Davis MINI E Consumer Study [20] participants "desire for a vehicle that is both environmentally friendly and fun to drive". Especially "the intersection of clean and fun" belongs to the "emerging areas of value for consumers". In a study by the Fraunhofer Institute ISI [17] participants rated environment-friendliness ("Umweltfreundlichkeit"), low noise level ("Geräuscharmut") and innovativeness ("Innovativität") as relevant advantages of e-mobility. Krems et al. [11] localize two needs EVs can satisfy, green driving ("grünes Autofahren") and driving pleasure ("Fahrspaß").

We chose the following selection of six positive characteristics, electromobility is connected to:

- Sustainable
- Energy-Efficient
- Clean
- Low-Noise
- Innovative
- Driving Pleasure

4. METHOD

We conducted an initial study with 13 participants (three female) with an average age of 22 years ranging from 19 to 27. The participants' task was to choose materials (see Figure 2) that they associate with the mentioned characteristics of electromobility.

All samples were provided by a sample box ("Modulor Musterkiste") containing 199 materials. We asked participants to select six out of 18 pre-selected materials (see Figure 1). Next, they assigned each material to one of the characteristics of electromobility shown on the multisensory mood-board. During the procedure, we asked participants to think-aloud about their emotions and explain details about their choice.

As a final step they commented on the completed mood-board (see Figure 3).

The characteristic terms of electromobility and the provided material selection were randomized for every participant according to a latin square.

5. RESULTS

'Innovative' was associated by 68% of the participants with Plastics (most frequent: soft polyvinyl chloride (PVC), 46%) because it was "novel and had a cool look" to most of them.

'Sustainable' was associated with a green artificial turf (material group: Textiles, Leather, Artificial Leather) by almost half of the participants (46%). Comments on this were that "it is organic and green is the color of sustainability".

For the characteristic 'Clean' the preferences were split between aluminum sheet (38%; because it is "easy to clean"; material group: Metal) and balsa wood (30%; because it is a natural product; material group: Wood & Cork).

Table 1: Frequency of Associations with electromobility by material group in percent

Material group	Frequency
Paper, Light & Strong Cardboard	9 (11.54 %)
Fleece Material & Felt	3 (3.85 %)
Wood & Cork	10 (12.82 %)
Textiles, Leather, Artifical Leather	16 (20.51 %)
Plastic & Rubber	34 (43.59 %)
Metal	6 (7.69 %)
Total	78 (100 %)

'Energy-Efficient' was associated by most of the participants (54%) with Plastics (most frequent: polystrol rigid foam, 23%). The reason for this was mainly "because of its heat insulation and low weight". Another 31% associated Paper, Light & Strong Cardboard (most frequent: comb-board, 23%), because of their production process using low energy and recyclable materials.

'Driving-Pleasure' was associated either with Metal (38%; most frequent: aluminum sheet, 23%) or with Artificial Leather (23%). The given reasons for the former are that the majority of sports cars are made of lightweight material like aluminum. The given reason for the latter is that the interior of cars associated with driving pleasures most of the times contains leather.

'Low-Noise' was associated with Plastics (45 %; most frequent: polyerthan light-foam, 23%) or with synthetic needle-felt (23 %; material group: Textiles, Leather, Artificial Leather) or with natural cork (15 %; material group: Wood & Cork). For all of these, participants assumed a high noise restraining quality.

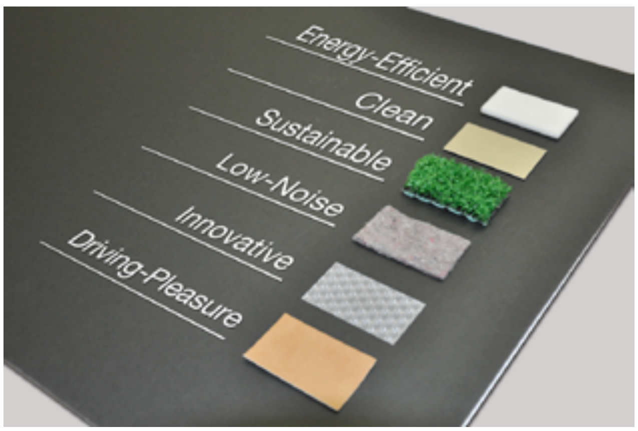

Figure 3: One exemplary multisensory mood-board. The participant chose the material polystrol rigid foam for the characteristic 'Energy-Efficient', the aluminum sheet for 'Clean', the artificial turf for 'Sustainable', the synthetic needle-felt for 'Low-Noise', the 3D soft-PVC for 'Innovative' and artificial leather for the characteristic 'Driving-Pleasure'

6. CONCLUSION AND FUTURE WORK

The aim of this study was to develop a new method to visualize users' associations and preferences of material regarding electromobility. The results show that there is a great variation in the degree of agreement about associated materials.

Participants seem to have a clear view about what materials represent concerning the characteristics 'Innovative' or 'Sustainable'. 'Innovative' was clearly associated with Plastics, especially 3D soft PVC. This material seems to be seen as cool and novel. For example, one participant noted: "the material is not common, looks innovative because of that, I have never seen it before". Another one stated: "looks cool, is novel and modern". 'Sustainable' was associated by most of the participants with artificial turf because of its green color and organic character. Most statements for 'Sustainable' were in the manner of the following: "looks like grass, like sustainability and future".

The associations for the other characteristics were mixed. For 'Clean' and 'Energy-Efficient', participants either thought about the appliance in the car or about the production process. For example in case of 'Clean', Metals are seen as clean because they are easy to clean, but balsa wood was also associated, because it is a natural product. In the same manner, 'Energy-Efficient' is either represented by Plastics, because of the assumed high heat insulation in the car, or by Light & Strong Cardboard, because of its energy saving production process. For example, one participant said about the comb-board "looks as if it is recyclable or was already recycled once".

The associations with 'Driving-Pleasure' are strongly influenced by the materials used in sports cars, e.g. aluminum for the chassis and leather for the interior. For instance: "Cars that are a pleasure to drive have always somewhere leather in them".

For the last characteristic, 'Low-Noise', materials that are assumed to be noise dampening were chosen, e.g. plastics or synthetics.

The given reasons for the choices reveal a first impression of how associations are formed and can be categorized into roughly three categories: the first category are associations based on the look (Innovative, Sustainable), the second category are associations based on the production process (Energy-Efficient, Clean) and the third category are associations based on the appliance in the car (Driving-Pleasure, Low-Noise, Energy-Efficient, Clean). Although, boundaries are not clear, as Energy-Efficient and Clean fit into two categories. However, the interpretation of the results has to be done with care as the sample size of the initial study was small and the range of participants' age was low. More studies with larger sample sizes and more representative samples should be conducted to confirm or revise the results and to clarify how and why associations between material and characteristics of electromobility are made.

The multisensory mood-boards (see Figure 3) can be seen as a tool to communicate associations users have with electromobility. The aim of this paper was not to identify special lightweight materials that could be introduced in electromobility. Instead, the multisensory mood-boards underline the importance of visualizing the users' preferences as a thought-provoking tool for knowledge generation in industrial design.

By the decision to choose real materials, we want to emphasize the importance of tangible expressions. This approach could include, besides the visual perception, also the senses of touch and smell.

For representative results of the visualized characters of electromobility it would be reasonable to repeat this study in a larger context in the future. The tool could be applied and verified to other topics as well.

Furthermore, it would be interesting to conduct a second study using only paper-based pictures instead of real materials to see if there are any differences in the participants' associations. This would be a follow-up on an interesting approach from Schifferstein and Cleiren [19] that analyzed the experiences with products using only one modality. This could be especially interesting for the materials that are associated with a characteristic because of their look.

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CLW 2013: The Third Workshop on Cognitive Load and In-Vehicle Human-Machine Interaction

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ABSTRACT
Interactions with in-vehicle electronic devices can interfere with the primary task of driving. The concept of cognitive load can help us understand the extent to which these interactions interfere with the driving task and how this interference can be mitigated. The workshop will address cognitive load estimation and management for both driving and interactions with in-vehicle systems, as well as the need for standardizing cognitive load-related concepts and experimental practices.

Categories and Subject Descriptors
H.5.2 Information interfaces and presentation: User Interfaces. H.5.1 Multimedia information systems.

General Terms
Design, Experimentation, Human Factors, Measurement.

Keywords
Cognitive load, estimation, management, driving.

1. INTRODUCTION
In-vehicle human-machine interaction (HMI) can interfere with the primary task of driving. The concept of cognitive load can help us understand the extent to which these interactions interfere with the driving task and how this interference can be mitigated [1]. While multiple definitions of cognitive load (also called cognitive or mental workload) appear in the literature (see [2] for a brief review), it is commonly defined as the relationship between the cognitive demands of a task and the cognitive resources of the user [3]. While research results on in-vehicle cognitive load are frequently presented at automotive research conferences and in related journals, CLW 2013, the third in the series [4], will provide a unique forum for focused discussions on this topic.

2. WORKSHOP GOALS
The workshop has four goals:

1. **Explore the concept of cognitive load:** While the concept of cognitive load has been used by a number of researchers working on in-vehicle HMI (as well as those working in other fields), the definition of cognitive load is still debated. What are the definitions of cognitive load used in industry and academia? How is cognitive load related to different aspects of driving and various in-vehicle secondary tasks? Workshop participants will discuss these questions and will propose their own definitions of cognitive load.

2. **Explore issues in cognitive load estimation:** In estimating cognitive load (on-road [5, 6] and laboratory-based [7, 8]), researchers and practitioners use three types of measures: performance, physiological and subjective. The workshop will explore the practical use of these measures. Specifically, participants will discuss estimation methods, including details such as measurement equipment, reference tasks, and experimental design.

3. **Explore issues in cognitive load management:** How can we design in-vehicle HMI such that the driver has the cognitive resources to safely operate the vehicle, even while interacting with in-vehicle devices? Researchers and practitioners have explored a number of approaches for workload management [9], from simply turning off HMI in certain situations, to introducing novel interaction methods which hopefully do not introduce undue cognitive interference with the driving task (voice interfaces [10, 11], augmented reality [12, 13], mediation [14], tactile interfaces [15], subliminal notifications [16], etc.). The workshop will explore various aspects of managing the driver's cognitive load.

4. **Explore the need for standardization:** In light of current approaches to cognitive load estimation and management, what are the areas of standardization that would be of the greatest benefit to researchers and practitioners? Workshop participants will discuss approaches of interest, including the introduction of standard definitions, toolsets, and corpora, which could

be used to make new results replicable and easily compared to the results of others.

The workshop organizers will bring together a number of experts from government, industry, and/or academia to address topics on exploring the concept of cognitive load (goal 1). Furthermore, we will solicit research papers exploring issues in cognitive load estimation and management for interactions with in-vehicle devices (goals 2 and 3). Authors will be encouraged to also include at least one paragraph addressing standardization (goal 4). Additionally, position papers on goal 4 will also be solicited. Topics of interest will include:

- Cognitive load estimation in the laboratory,
- Cognitive load estimation on the road,
- Sensing technologies for cognitive load estimation,
- Algorithms for cognitive load estimation,
- Performance measures of cognitive load,
- Physiological measures of cognitive load,
- Visual measures of cognitive load,
- Subjective measures of cognitive load,
- Methods for benchmarking cognitive load,
- Cognitive load of driving,
- Cognitive overload and cognitive underload,
- Approaches to cognitive load management inspired by human-human interactions.

3. WORKSHOP ORGANIZATION

3.1 Before the Workshop

3.1.1 Program Committee Recruitment

The program committee will be recruited from the extensive list of academic and industry contacts of the organizers, in the HCI, speech, ubiquitous computing, and human factors and ergonomics communities. We will primarily target our colleagues who were part of the PC in 2011 and 2012.

3.1.2 Publicity and Soliciting Papers

The workshop will be publicized using a dedicated website hosted by the University of New Hampshire. The Call for Papers will be distributed via the following channels:

- ACM CHI mailing list,
- Ubicomp mailing list,
- SIGdial mailing list,
- WikiCFP,
- HFES Surface Transportation Technical Group Newsletter,
- Driving Assessment conference email list;
- Contacts of program committee members in their respective fields.

3.1.3 Paper Submission, Review and Selection

Papers will be submitted and reviewed using the EasyChair conference management system [17]. This will allow for online paper submission and simple management of reviewer assignments and feedback. The organizers will make the final paper selection based on reviewer recommendations. Note that EasyChair is a free service hosted by the University of Manchester CS Department; therefore no funding will have to be secured for its operation.

3.1.4 Final Pre-Workshop Activities

The list of accepted papers will be posted on the workshop website in early October. The organizers will create a mailing list to distribute accepted papers to workshop participants prior to the workshop. Participants will also be encouraged to use the mailing list to initiate interactions before the workshop.

3.2 During the Workshop

3.2.1 Sessions

This all day workshop will start with a keynote address and continue with three sessions.

Keynote by Klaus Bengler. Dr. Bengler is professor at the Technische Universitat Munchen. One of his primary focus areas is in-vehicle human-computer interaction. In his keynote Dr. Bengler will discuss issues of driver availability (underload vs. overload situations).

Session 1: Expert presentations on cognitive load and in-vehicle HMI. The first session will feature 2-4 experts who will discuss their views on the concept of cognitive load: what it is, how to estimate it, and what its role is in exploring in-vehicle HMI. The session will include a presentation by Toyota's James Foley, who will discuss NHTSA guidelines for the design of in-vehicle HMI and their relationship to cognitive load.

Session 2: Contributed presentations on cognitive load and in-vehicle HMI. Session 2 will feature oral presentations by workshop participants introducing papers accepted for publication by CLW 2013. The presentations will focus on cognitive load estimation and management, specifically the topics listed at the end of section 2.

Session 3: Sharpening our arguments. In the final session we will invite all participants to discuss the contributed presentations (Session 2), especially in light of the keynote and the expert presentations (Session 1). We will offer the following seed questions for this discussion:

1) Are the problems, goals and hypotheses of the contributed presentations well-defined and grounded in existing knowledge? How could they be improved based on the keynote and expert presentations?

2) Did the authors of the contributed presentations consider all interesting questions that are raised by their work? Are there aspects of their discussion and conclusions that could be improved?

3) Are the presented results repeatable? What are the aspects of cognitive load-related research that should be standardized?

3.2.2 Collecting Feedback

As in 2011 and 2012, at the end of the workshop organizers will solicit feedback from participants in anonymous written form. Participants will be asked to evaluate the relevance and ultimate value of the workshop using responses on a Likert scale. Suggestions for improvements will also be solicited.

3.3 After the Workshop

3.3.1 Online Report

Based on the notes taken during the workshop, the organizers will create a report about the workshop's outcomes and post it on the workshop website. The organizers will also report on participant evaluations.

3.3.2 White Paper(s) on Future Work

The organizers will initiate an effort to prepare a white paper to provide guidance on future work in the field of cognitive load as it relates to in-vehicle HMI. The intended consumers of this guidance are fellow researchers and developers, industry, and funding agencies.

3.3.3 Workshop at AutomotiveUI 2014?

Assuming that participant feedback indicates that the workshop was successful, the organizers will contact participants for suggestions for a workshop to be held at AutomotiveUI 2014.

4. ACKNOWLEDGMENTS

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CLW 2013 Keynote Address: Cooperative Driving as a New Paradigm for Highly Automated Vehicles

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ABSTRACT

More than 125 years of automobility remind us that we should be aware of the fact that individual mobility is based on the fact that the driver contributes exceptionally high activity and human performance in the human-vehicle system. Besides improved vehicle technology this human factor is crucial to avoiding accidents in critical situations. However, critical incidents and accidents can often be caused by human error or limited capacity. Since the 90s these effects have been successfully countered with a variety of driver assistance functions. Sensory deficits of the driver and misperceptions are compensated by technical sensors. Drivers use these assistance systems temporarily and shall be assisted in the execution of sub-tasks of the driving task where they remain – following the Vienna Convention – in the supervisory role.

Much of the automotive period is thus characterized by the fact that the driver must manage the driving task for the most part alone and may delegate sub-tasks only for a short time. The great advantage of the car was a significant gain in mobility, based on various assistants, in addition to the additional active safety, leading to sometimes monotonous driving. The potential automation or partial automation of driving is not only more of the same but a radical qualitative and quantitative change in individual mobility, provoking many questions in the area of human factors and human-vehicle interaction.

AutomotiveUI'13, October 27-30, 2013, Eindhoven, The Netherlands
Adjunct Proceedings

Implications of NHTSA Visual Manual Guidelines to the Design and User Experience of In-vehicle Interfaces

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ABSTRACT

NHTSA released visual manual guidelines in 2013 to limit the potential of distracted driving caused by in-vehicle telematics by loosely tying together guidelines published by the Alliance and JAMA, and adding additional parameters such as "per se lockouts". While the implications to each automotive OEM may vary greatly, these guidelines have the potential to severely limit vehicle cockpit design and user interfaces which are at the core of the driving experience. NHTSA plans to reign in the automakers by increasing the scope and depth of vehicle systems by limiting non-driving tasks such as telematics, navigation, and entertainment to lower than the levels used by the Alliance and by including driving related tasks such as cruise and climate controls.

A caveat – most experts agree that a severely restricted in-vehicle interface will further push the driving population to use the handheld devices which have been documented to be inappropriate for use while driving but which allow for an unrestricted user experience. While the unintended safety implications of a heavily restricted in-vehicle interface and an unrestricted handheld interface is as yet unknown, this area of driver distraction will continue to be the forefront of research and debate for quite a while to come.

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Adjunct Proceedings

Warwick-JLR Driver Monitoring Dataset (DMD): A public Dataset for Driver Monitoring Research

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ABSTRACT
Driving is a safety critical task that requires the full attention of the driver. Despite this, there are many distractions throughout a vehicle that can impose extra workload on the driver, diverting attention from the primary task of driving safely. If a vehicle is aware that the driver is currently under high workload, the vehicle functionality can be changed in order to minimize any further demand. Traditionally, workload measurements have been performed using intrusive means such as physiological sensors. We propose to monitor workload online using readily available and robust sensors accessible via the vehicle's Controller Area Network (CAN). The purpose of this paper is to outline a protocol to collect driver monitoring data and to announce the publication of a database for driver monitoring research. We propose five ground truths, namely, timings, Heart Rate (HR), Heart Rate Variability (HRV), Skin Conductance Level (SCL), and frequency of Electrodermal Responses (EDR). The dataset will be released for public use in both driver monitoring and data mining research.

Keywords
Driver monitoring, Data collection, EDA, ECG, CAN-bus

1. INTRODUCTION
Driving is a safety critical task that requires the full attention of the driver. Despite this, modern vehicles have many devices with functions that are not directly related to driving. These devices, such as radio, mobile phones and even internet devices, divert cognitive and physical attention from the primary task of driving safely. In addition to these distractions, the driver may also be under high workload for other reasons, such as dealing with an incident on the road or holding a conversation in the vehicle. One possible solution to this distraction problem is to limit the functionality of in-car devices if the driver appears to be overloaded. This can take the form, for example, of withholding an incoming phone call or holding back a non-urgent piece of information about traffic or the vehicle status.

It is possible to infer the level of driver workload from observations of the vehicle and the driver. Based on these inferences, the vehicle can determine whether or not to present the driver with new information that might unnecessarily add to their workload. Traditionally, such systems have monitored physiological signals such as heart rate or skin conductance [3, 13, 7]. However, such approaches are not practical for everyday use, as drivers cannot be expected to attach electrodes to themselves before driving. Other systems have used image processing for computing the driver's head position or eye parameters from driver facing cameras, but these are expensive, and unreliable in poor light conditions [9].

We therefore use non-intrusive, inexpensive and robust signals, which are already present in vehicles and are accessible by the Controller Area Network (CAN) [4]. The CAN is a central bus to which all devices in the vehicle connect and communicate by a broadcast protocol. This allows sensors and actuators to be easily added to the vehicle, enabling the reception and processing of telemetric data from all modules of the car. This bus and protocol also enables the recording of these signals, allowing us to perform offline data analysis and mining. In mining this data, we aim to build a system that can recognise when a driver is overloaded and then act accordingly. Our initial work has shown that features extracted from the CAN are able to support machine learning models for predicting the cognitive load of a driver [11] or

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the state of a vehicle, such as the current road type [10].

This paper proposes a procedure for acquiring a dataset for this driver monitoring problem, in the form of a supervised classification task. The ground truths are taken from both experiment timings and physiological measures, namely Electrocardiography (ECG) and Electrodermal Activity (EDA). The remainder of this paper is structured as follows. In Section 2 we outline the experimental protocol that is be used to distract the driver during data collection. Section 3 describes the CAN-bus data in more detail and states how the ground truth is be achieved. Finally, in Section 4 we give details of the format of the data and its release and briefly discuss its potential impact on driver monitoring research.

2. EXPERIMENTAL PROTOCOL

The experimental protocol we use is based on that performed by Reimer *et al.* [9] and Mehler *et al.* [7], and is outlined in Table 2. In their work, changes in physiology and driving style are observed while the driver is performing the N-back test as a secondary task to driving. The main difference in our protocol is that we perform it on a test track and the ECG electrodes are on the chest rather than the lower neck. Also, we use gel EDA electrodes with adhesive pads, as we have found these are more stable and, in our experience, produce a cleaner signal.

Our implementation of the protocol runs as follows. First, when the participant arrives, electrodes are attached for both the ECG and EDA measurements. After this, the participant is taken to the vehicle and seated in the driving position. Once the seat, steering wheel, and mirrors are adjusted as appropriate, data recording is commenced. The protocol then continues with checking that the sensors are providing a clean and reliable signal, followed by practice runs of the N-back tests (stages 1 and 2).

The N-back test requires the participant to repeat digits provided to them in a list with a delay. Here it is operated with three forms of increasing difficulty, with delays of 0, 1 and 2 and referred to as the 0-, 1- and 2-back tests respectively. These three difficulty levels have been shown to have an increasing impact on the participant's physiology and driving style [7, 9]. In the 0-back test, the participant is required to repeat digits back as they are said. The 1-back test requires the participant to repeat the digits with a delay of 1, and the 2-back test with a delay of 2. Each task is presented in 4 blocks of 10 digits, with a time separation between each digit of around 2.5 seconds. An example block of 10 digits is shown in Table 1, with expected responses for the 0-, 1- and 2-back tests. In order to continue with the experiment, the participant must show a minimum proficiency of 8 out of 10 correct responses for two consecutive blocks of each task.

In order to have a controlled environment and minimize unexpected events, the protocol must be performed on a simulated highway test track. This track is quiet in comparison to real world roads, has 4 lanes, and is used solely by automotive engineers who may be using the track at the same time as the experiment. The participants are instructed to drive in the second lane at usual highway speeds of around 70mph, changing lanes to overtake when necessary. Because this is likely to be an unfamiliar vehicle and a new environment for the participants, a habituation period is used (stage 3). Before the commencement of the habituation period, the vehicle is driven onto the track by the participant.

Stimulus	1	5	9	3	0	2	3	3	2	9	&	&
0-back	1	5	9	3	0	2	3	3	2	9		
1-back	-	1	5	9	3	0	2	3	3	2	9	
2-back	-	-	1	5	9	3	0	2	3	3	2	9

Table 1: Example of the N-back test with a block of 10 numbers. In place of "&" the word "and" is said by the experimenter, requiring the participant to provide a response. Where there is a "-" no response is required by the participant.

	Stage	Time (minutes)
1.	Sensor verification	2:00
2.	Task practice	5:00
3.	Habituation period	25:00
4.	Drive (reference)	3:00
5.	N-back test A	2:30
6.	Drive (recovery)	3:00
7.	N-back test B	2:30
8.	Drive (recovery)	3:00
9.	N-back test C	2:30
10.	Drive (recovery)	3:00
	Total	51:30

Table 2: The protocol for the experiment, employing three N-back tests of different difficulties, presented in a random orders.

Once the driver is comfortable on the track, a reference period under normal driving is used (stage 4), with all sensors being recorded. At stage 5, after this reference period, the protocol alternates between N-back tests and recovery periods of normal driving (stages 5–10). Each participant undergoes each of the 0-, 1- and 2-back tests in a random order. Each of the N-back tests consists of 4 blocks of 10 digits, with a block separation of 5s. At the beginning of the first of the 4 blocks, a brief explanation and reminder of the test being performed is provided. This explanation takes 30s, while the four blocks take the remaining 2 minutes posted in Table 2. The recovery periods are each of normal driving, with no secondary task. Once each task has been performed and the final recovery period has taken place, the vehicle is then taken off the track and data recording is ended.

3. DATA COLLECTION

There are over 1000 signals that can be recorded from the vehicle's CAN-bus. Those signals which are expected to have relevance to driver workload include, steering wheel angle, pedal positions and vehicle speed. Many others are likely of no relevance to driver monitoring and should be removed before attempting to predict driver workload. However, to ensure that all the relevant signals are present in the dataset, we recorded the full set of signals at a sample rate of 20hz during the experiment. Each of these signals was written to a hard disk by a data logging system located under the passenger seat.

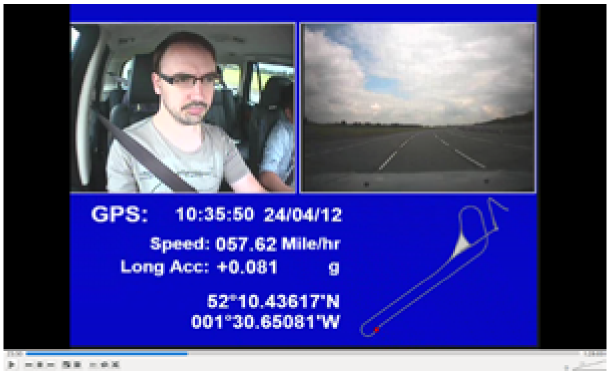

Figure 1: Screen shot of the video output recorded during the experiment, with driver and forward facing cameras and GPS details overlaid.

ECG and EDA signals were recorded via a GTEC USB biosignal amplifier (USBamp). Three point ECG gel electrodes were attached on the driver's chest, close enough together to minimize any noise generated through shoulder movement. The adhesive gel EDA electrodes were attached on the participant's non-dominant hand, on the underside of the index and middle fingertips. Surgical tape was then used to further secure them in place, minimizing any movement of the sensor contacts while driving. The wires from the ECG electrodes came out of the top of the participants shirt, while the EDA wires were positioned to the side of the non-dominant hand. Note that the vehicle used has an automatic transmission and the driver does not need to use their hands for gear selection.

The GTEC USBamp resides in the rear of the vehicle, with sensor wires positioned away from any intrusion of the driver. This connects to a laptop, where the data was recorded at 256Hz. The laptop also had input from the CAN-bus time signals for synchronization purposes, which is provided at 10Hz. In order to match these signals in time, therefore, some re-sampling is performed. Further to this, driver and forward facing cameras record video throughout the experiment, with GPS time overlaid on the image, as shown in Figure 1.

From this data, there are five ground truths that we use to produce classification problems. These are extracted from the timings of the tasks during the experiment, the EDA signal, and the ECG signal. The timings of the tasks provides a ground truth of what the participant was doing at a given point in time. The EDA signal provides two measurements, the Skin Conductance Level (SCL) and frequency of Electrodermal Responses (EDR), both of which are known to increase while a participant is under high workload [7, 5, 1]. The skin conductance level is provided by the absolute value of the EDA signal, whereas EDRs are found by spikes, as illustrated by the red dots on the EDA signal in Figure 2. Finally, two ground truths can be extracted from the time differences between R-peaks, highlighted by the red dots on the ECG signal in Figure 3. Heart Rate (HR) is calculated as the number of R-peaks per minute, whereas Heart Rate Variability (HRV) is a measure of the variation of the time

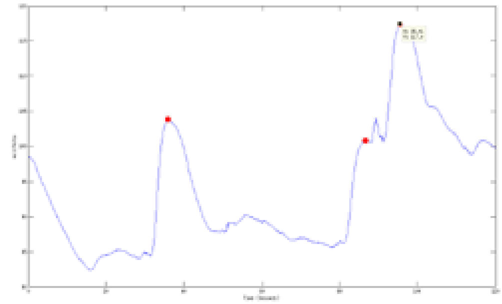

Figure 2: Two minutes of an EDA signal recorded during driving. The red dots highlight EDRs, which increase in frequency under workload. The SCL is given by the signals absolute value.

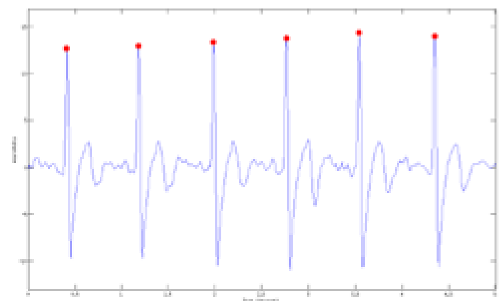

Figure 3: Five seconds of an ECG signal recorded during driving. The red dots highlight the R-peaks, which can be used to compute the HR and the HRV.

delays between R-peaks [7, 2, 5, 8]. Under higher workload demands, HR is known to increase and HRV has been shown to decrease. In computing HRV we opt to use *Standard Deviation of Successive Differences* (SDSD) of RR-intervals, as a result of findings by Mehler *et al.* [8].

From each of these ground truths, both binary and multi-class classification problems are constructed. The binary classification problems all have class labels of *Normal* driving and *Distracted* driving. If the timings ground truth is used, the label is *Normal* unless a secondary task is being performed, in which case it is *Distracted*. For all the other ground truths, a value close to the baseline is *Normal*, and a significant change from the baseline is *Distracted*.

The multi-class classification problems are very similar, but the *Distracted* label takes account of different amounts of difficulty, workload or physiological response. For instance, the timings ground truth can provide three levels of difficulty of the secondary task, relating to which of the 0-, 1- and 2-back tests were being performed. From the HR, HRV and EDA signals, the amount of change can be used in providing more detail on the level of workload, such as a small change, medium change, or large change. In these cases, the labels are be *Normal*, *Low*, *Medium* and *High*, relating to the difficulty or workload level.

For this dataset we executed the protocol with 20 participants, selected from people who are regular drivers, but who have not previously driven on the test track. A Range Rover Sport was used, and was the same vehicle throughout to maintain consistency for both the CAN-bus data and each participant. The direction of the test track is reversed once per week, meaning that around half the participants travel clockwise, and around half travel anti-clockwise.

4. DATA RELEASE

The dataset is available for download via `www.dcs.warwick.ac.uk/dmd/` in a comma separated variable (csv) format, with samples in temporal order at 20Hz. Each of the 10 class labels are be provided for each of these samples. The physiological data are also be available, as this may have other uses to researchers. This physiological data has timestamps, so that it can be associated with the CAN-bus data, but the sample rate remains at 256Hz.

Because many of the signals recorded are be irrelevant to the problem, these have been removed before the release of the dataset. To avoid any human selection bias, correlation analysis with Mutual Information (MI) [12] is used; where features with a MI below a threshold have been removed. Some of those which are kept have been obfuscated so that commercially sensitive details of the CAN-bus and telemetry signals are not made publicly available.

The production and release of such a dataset may benefit both the driver monitoring and data mining communities. The data naturally has high autocorrelation, and several irrelevant and redundant signals; all of which affect the performance of a classification system [6]. As well as this, some of the signals may be correlated with time, introducing biases. Overcoming these issues is not only essential to predicting driver behaviour, but they are also difficult problems for data mining in general. We provide a central dataset against which driver workload monitoring methods and temporal data mining techniques can be evaluated and compared.

5. CONCLUSION

In this paper we have outlined a procedure for collecting a dataset for the driver monitoring problem. Five ground truths are provided, taken from experiment timings and physiological data. The experiment timings contain when a secondary task is being performed, and which task that was. The physiological data, namely ECG and EDA, provide HR, HRV, SCL and frequency of EDRs as ground truths, each providing two sets of class labels.

This dataset will be released for public use, with several vehicle telemetry signals and the 10 class labels. As well as this, the raw physiological data will be released, as this may be used for other forms of analysis.

If the outcomes of analysis of this dataset and collection procedure are positive, then we intend to use a similar set-up for collecting a second dataset, which is more representative of real world driving. For instance, it would be more realistic if EDA or ECG could be used for ground truth, independent of a secondary task such as the N-back test. In future, therefore, subjects may be made to drive for long periods of time under normal circumstances on public roads. The ECG and EDA sensors might then provide a reliable ground truth for real world workload, for use in a classification task.

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PHYSIOPRINT: A Workload Assessment Tool Based on Physiological Signals

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ABSTRACT

In this paper we introduce a novel workload assessment tool (called PHYSIOPRINT) that is based on the combination of two types of physiological signals: electroencephalography (EEG) and electrocardiography (ECG). The tool is inspired by a theoretical workload model developed by the US Army that covers a large number of different workload types relevant for driving scenarios, including auditory, visual, cognitive, and motor workload. The PHYSIOPRINT classifier was trained on the EEG and ECG data acquired during well-defined atomic tasks chosen to represent the corresponding types of workload. The trained model was validated on realistic driving simulator data from an independent study. The highest performance on the atomic tasks was achieved for visual workload, with precision of 91.8% and recall of 94.1%. The corresponding classification results in the validation study were: precision 78.3% and recall 80.6%. The utilized classification approach is not computationally expensive, so it can be easily integrated into automotive applications.

Categories and Subject Descriptors

H.1.2 [**Information Systems**]: User/Machine Systems – *human factors, human information processing, software psychology.*

General Terms

Algorithms, Measurement, Performance, Experimentation.

Keywords

Workload, electroencephalography, electrocardiography, driving simulator, physiology.

1. INTRODUCTION

Due to the rapid advances in technology and related changes in consumers' lifestyles and expectations, the motor vehicle industry will likely continue to integrate more sophisticated entertainment and information systems in new vehicles. The increasing complexity of interactions with in-vehicle equipment and the unprecedented amount of information streaming from these devices, however, create a palpable threat that drivers might find themselves overloaded with information that distracts them from the primary task of driving. This persistent and, in many cases, self-inflicted mental strain may cause driving performance decrements and lead to a substantial increase in the number of accidents with potentially grave consequences. One way to mitigate this issue is to study the driver's interactions with new in-vehicle technologies and use that knowledge to optimize system design and operating procedures. In order to accomplish this goal, we need an unobtrusive and objective measure of the driver's workload that not only quantifies average workload levels over long periods of time, but is also able to continuously capture workload variations throughout the task.

Workload is typically defined as the amount of mental or physical resources required to perform a particular task [19]. Its quantification is, unfortunately, difficult in practice because each individual's capacity of available resources varies greatly, as do the strategies for using them. The standard techniques used for workload assessment include self-report scales, performance-based metrics, and physiological arousal measures. Self-report measures are popular due to their low cost and consistency, though the latter quality assumes that the individual is cooperative and capable of introspection and accurate reporting of their perceived workload. Some of these scales are one-dimensional such as the Rating Scale of Mental Effort (RMSE) [24] and the Modified Cooper-Harper scale (MHC) [6], whereas some scales comprise subscales that measure specific mental resources, e.g., NASA Task Load Index (TLX) [9], Subjective Workload Assessment Technique (SWAT) [17], and Visual Auditory Cognitive Psychomotor method (VACP) [23]. The major drawback of these measures is that they cannot be unobtrusively administered during the task itself, but are assessed retrospectively at the conclusion of the task, which decreases accuracy of this technique. Furthermore, the inherent subjectivity of self-ratings makes across-subjects comparisons difficult. Self-report scales are, therefore, often complemented with an objective assessment of performance; this operates on the assumption that an increased workload diminishes performance. Performance measures include reaction time to different events, accuracy of responses, and overall driving performance such as steering wheel angle or lane position. The performance assessment is relatively unobtrusive and can be accomplished in real time at low cost as an indicator of actual workload level. Performance, however, is not sensitive enough to workload changes due to the complex relationship between the two variables. Performance is typically stable across a range of workload levels and deteriorates only near the extremes [18]. Moreover, performance measures cannot tap into all cognitive resources with comparable accuracy. Lately, there has been renewed interest in physiological measures as useful metrics for assessing workload. Their use was limited in the past by the obtrusive nature of earlier instrumentation, but this has changed with the advent of miniaturized sensors and embedded platforms capable of supporting complex signal processing techniques. Typically used physiological signals to derive measures of workload include: electrooculography (EOG) [7], electromyography (EMG) [22], pupil diameter [11], electrocardiography [20], respiration [5], electroencephalography [3], and skin conductance [19]. In some studies, physiological measures have been reported as being more sensitive to the initial changes in workload than performance-based measures, as they

Figure 1. Driving Simulator at STI.

Figure 2. A subject wearing the wireless B-Alert sensor headset while performing an atomic task.

Forward/Backward Digit Span (FBDS). The subject sits still in front of a computer screen and memorizes sequences of 2 up to 9 digits that are shown on the computer screen and reproduces them by typing in the memorized sequence in the same or reverse order.

Fine Motor Control Task (FMCT). The subject holds a needle and inserts it into a target hole on a metal plate that is positioned at a 45º angle, and is instructed to keep the needle within the circular hole for 10sec without touching its perimeter. This was repeated for 5 holes whose diameters were 8, 7, 6, 5, and 4/32ths of an inch. The needle diameter was 3/64in.

Dominant workload types and the corresponding IMPRINT workload scores for the atomic tasks are as follows: ADET - auditory (1.0); VDET - visual (3.0); VDI - visual (5.0) and cognitive (3.7); FBDS - cognitive (5.3); and FMCT - fine motor (2.6) and visual (4.0).

2.2.2 Driving Simulator

The developed driving scenarios differed with respect to continuous visual-motor workload (related to the road curvature and a number of obstacles to be avoided) and the number of discrete events that were designed to cover a variety of activities on the visual, auditory, cognitive, and fine motor IMPRINT workload scales. There were three different sensory challenges during each scenario: (1) *auditory challenge* - honking (one of three possible patterns), (2) *visual challenge* - arrow signs pointing to one of the four possible directions, and (3) *cognitive challenge* - speed signs of two different colors (white and yellow) placed along the road requiring the subjects to add (if yellow) or to subtract (if white) the 3-digit numbers shown on the sign. The expected response to the visual and auditory challenges was a button press (*fine motor response*), verbal acknowledgment (*speech*) or no response (*cognitive action*), depending upon the arrow direction and the honking pattern. During the rides (Figure 1), the subjects sat on a gym bicycle whose front panel had been removed to avoid obscuring the view at the driving simulator screen. After the first 5min of the ride, the subjects were told to start pedaling till the end of the scenario (*gross motor* load).

The whole period from the onset of a particular stimulus (honking, arrow, and sign) till either its disappearance or the subject's response to it was considered a period with the dominantly auditory, visual, or cognitive workload, respectively. The 1-sec segments of the EEG and ECG that were completely or partially (>50%) covered by that period would consequently receive the same IMPRINT workload score (5.0 on the visual scale for the visual challenge, 6.6 on the auditory scale for the auditory challenge, and 7.0 on the cognitive scale for the mathematical challenge). The 2-sec periods centered around the subject's response (or, in case of the 'silent' response, the 2-sec period around the moment of the stimulus disappearance) received the appropriate score on the IMPRINT fine motor (score 2.2), speech (score 2.0), or cognitive (score 4.6) scales. The rest of the ride was scored with 4.4 on the visual ('visually track/follow') and 2.6 on the fine motor scale ('continuous adjustive control'). The portions with the pedaling also received a score of 3.0 on the gross motor scale.

2.3 Data Recording and Signal Processing

The wireless B-Alert sensor headset [1] (Figure 2) was used to acquire the EEG and ECG data of all subjects in the studies. The EEG data were recorded from 9 sites on the head (F3, F4, Fz, C3, C4, Cz, POz, P3, and P4 locations of the 10-20 international system), referenced to link mastoids. The ECG data were recorded from two electrodes placed on the left and right collar bone. All signals were filtered with a band-pass filter (0.1-70Hz, roll-off: 20dB/decade) before the analog to digital conversion (256Hz, 16 bits/sample), and transferred in real time via Bluetooth link to a nearby PC where the data was stored onto a disk. The sharp notch filters were applied to remove environmental artifacts from the power network. The algorithm [1] was utilized to automatically detect and remove a number of artifacts in the time-domain EEG and ECG signals, such as spikes caused by tapping or bumping of the sensors, amplifier saturation, or excursions that occur during the onset or recovery of saturations. Eye blinks and EMG were identified and decontaminated by an algorithm [2] based on wavelet transformation. Eye blinks and EMG bursts were also used as binary variables (present/absent) in the PHYSIOPRINT workload model.

From the filtered and decontaminated EEG signal, the absolute power spectral densities (PSD) were calculated for each 1sec epoch of data by applying the short-term Fourier transformation (STFT). The following PSD bandwidths were extracted: delta, theta slow, theta fast, theta total, alpha slow, alpha fast, alpha total, sigma, beta, and gamma. In order to account for individual differences in the EEG data, we also utilized relative PSD values by subtracting the logged absolute PSD values for each 1Hz bin from the total logged PSD in the bandwidth of interest. Wavelet coefficients were also derived for each EEG channel in the exponential 0-2, 2-4, 4-8, 8-16, 16-32, and 32-64Hz bands. In some rounds of the model development, the same variables were extracted from the left-right and anterior-posterior differential EEG derivations that were constructed by subtracting the pertinent referential signals (i.e., Fz-POz, Cz-POz, F3-P3, C3-P3, F4-P4, C4-P4, F3-F4, C3-C4, and P3-P4). The proprietary physiological measure of alertness and mental fatigue (MF) was also calculated from the Fz-POz and Cz-POz derivations using our validated B-Alert algorithm [10]. The ECG signal was processed by a real-time algorithm that determined the inter-beat (R-R) intervals and heart rate. Measures of the heart rate variability (HRV) were derived from the R-R time series, such as NN50/NN20 (number of successive R-R intervals in the past 10sec that differ by more than 50ms and 20ms, respectively) and RMSSD (the square root of the mean squared difference of successive RR intervals). All the extracted variables were then also averaged over a 5sec sliding window in 1sec increments to include a short term history.

2.4 Data Analysis

The goal of the data analysis was to test four hypotheses:

H1: Classification results will be increased if a combination of complementary input signals (EEG and ECG) is relied on instead of a single modality (EEG).

H2: Classification results will be increased if multiple EEG channels from different areas of the scalp are utilized as opposed to reliance on only a few channels from adjacent regions.

H3: Classification results will be increased if concurrent measurement of levels of fatigue and alertness is performed and these measures are fed to the classifier.

H4: Classification results will be increased if the workload model relies on relative variables and descriptors of a period of time leading to the current moment and not only on descriptors of the current point in time.

The predictor variables were identified by the step-wise variable selection procedure on all available data. To test the hypotheses H1-H4, variable selection was repeated several times within four different feature spaces:

FS1 - the EEG variables derived only from the referential channels (EEG-REF);

FS2 - the EEG variables derived from both referential (EEG-REF) and differential channels (EEG-DIFF);

FS3 - the EEG-REF, EEG-DIFF and all ECG variables; and

FS4 - the EEG-REF, EEG-DIFF, ECG and mental fatigue scores (MF), i.e. all available variables.

Two separate rounds were conducted in each of the four feature spaces:

- 'No history' round, where the feature vectors included only variables calculated on the current segment, and

- 'Short-term history' round, where the feature vectors included averaged variables calculated for each of the 5sec prior to the current segment.

The selected variables were then used for building PHYSIOPRINT, which is a two-level classifier depicted in Figure 3. The first level outputted the dominant and second-dominant workload (WL) types: WLD and WLS, respectively. It included four independent classifiers, linear discriminant function analysis (L-DFA) [8] that fitted a multivariate normal density to each class

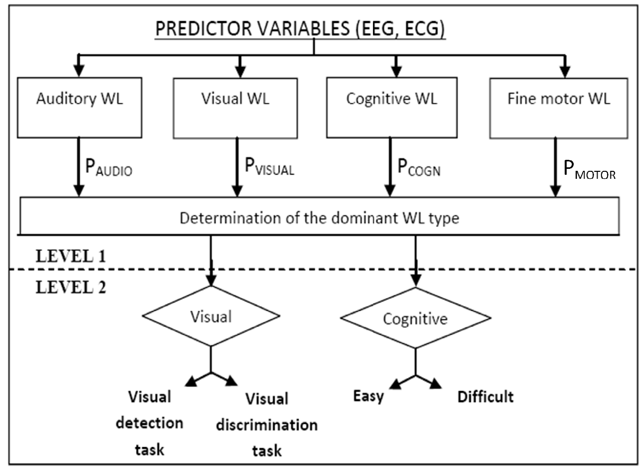

Figure 3. Two-level PHYSIOPRINT classifier.

with a pooled estimate of covariance. Based on the likelihood estimates and prior probabilities, the posterior probabilities (i.e., P_{VISUAL}, P_{AUDIO}, P_{COGN}, and P_{MOTOR}) that the given segment of data originated from a visual, auditory, cognitive, or fine motor workload task were calculated, respectively. The four classifiers were followed by a 'winner takes all' block that declared the WL type with the highest probability as the dominant type (WLD). In some cases, the second-dominant WL type was defined as the type with the second highest probability, but only if that probability exceeded a fixed threshold (PTH = 0.3). Level 2 of the PHYSIOPRINT classifier further quantified workload intensity within the dominant WL type. Level 2 comprised only two L-DFA classifiers: one that differentiated between the visual detection (score = 3.0) and visual discrimination task (score = 5.0), and one that further classified the cognitive task as easy (1-3 digits) or difficult (4-9 digits).

2.5 Evaluation Procedure

Once the predictor variables were selected for each combination of the feature spaces and history, the WL type-specific classifiers were evaluated using the leave-one-subject-out approach to assess the generalization capabilities of the classifier by testing it on the data that was not used for training. The model was first trained on all pertinent segments from 39 subjects (21 in the case of the Fine Motor WL classifier) and then tested on the remaining subjects. The procedure was repeated for all subjects in the study, and the results were averaged across all cross-validation rounds. This is a standard approach in the literature when dealing with relatively small sample sizes.

Furthermore, validation of the PHYSIOPRINT classifier was performed on the driving simulator data. Given the relatively small sample size in the driving simulator experiment, we limited our analyses to cross-validation of the Level 1 PHYSIOPRINT model. Only the best performing model was employed, and only its ability to recognize the dominant workload type was tested, i.e., the output of Level 2 was ignored at this stage.

3. EXPERIMENTAL RESULTS

In this section, we report on the most discriminative variables, PHYSIOPRINT classification results, driving simulator performance results, and cross-validation of the PHYSIOPRINT model on the driving simulator data.

3.1 Selected Variables

The variables selected in each round and feature space varied in number and type, but certain trends were observable in each round: (1) When the differential EEG variables were part of the feature space, they were dominantly selected, especially PSD bandwidth variables for the inter-hemispheric derivations (F3-F4, C3-C4, P3-P4); (2) When the ECG variables were part of the feature space, the heart rate (HR) variable was always selected as significant (but most of the HRV variables were not); (3) When the B-Alert measure of mental fatigue was included in the feature space it was selected; (4) The EEG variables mostly came from the theta (3-7Hz) and beta (13-32Hz) range; (5) The binary eye blink variable was selected for the Visual and Cognitive WL classifiers, but not the Auditory or Fine Motor WL classifiers; and (6) The EMG bursts derived from the EEG channels were never selected as significant.

3.2 PHYSIOPRINT Classification Results

In this section, we present classification results for both Level 1 (i.e., differentiation among different workload types) and Level 2 (i.e., differentiation between the workload levels on the same WL type scale) of the PHYSIOPRINT model.

3.2.1 Level 1 Classification Results

The summary results for all combinations of the feature space (FS1-FS4) and feature vector duration (1sec vs. 5sec) are shown in Table 1 for the visual, auditory, and cognitive workload type. As one can observe, the results confirm all four hypotheses (H1 - H4), and show that the multi-channel EEG and ECG signals successfully differentiate between the auditory, visual, and cognitive WL types (>80% precision/recall). Comparatively, the largest improvements were achieved with the addition of the differential EEG channels (~8% increase on average for the same feature vector duration), and with the increase in the feature vector duration (~4%-10% increase, depending on the WL type and feature space); the addition of ECG variables and EEG-based mental fatigue (MF) measures brought about moderate improvements (2-4% depending on the WL type). These variables may, however, be more important in situations when high stress is experienced (ECG), or when more complex visual or auditory tasks are pursued (MF).

The Fine Motor WL classifier's accuracy was not shown in the same table because this portion of the PHYSIOPRINT model could only be tested on a subset of subjects who had performed the FMCT task. The accuracy of this classifier showed similar trends (i.e., an increase with the addition of the differential EEG, ECG, MF and/or extension of the feature vector from 1sec to 5sec), but the values were relatively lower for any tested combination of the feature space and feature vector duration. The highest recall and precision – 62.7% and 68.3%, respectively – were obtained with all variable types (i.e., EEG-REF, EEG-DIFF, ECG, and MF) and 5sec long feature vectors. The data segments from the FMCT task were typically misclassified as 'Visual WL'. We attribute this, at least in part, to a substantial overlap between fine motor and visual workload during the execution of the fine motor (FMCT) task. Indeed, the Fine Motor WL was identified as the second-dominant WL type in 30% - 40% of the misclassified segments (the exact proportion varied with the feature space and feature vector duration). Therefore, the modest accuracy of identification of the Fine Motor WL type seems to be related to the impurity of the task that was nominally declared as the fine motor control task.

Table 1. Recall (REC, %) and precision (PREC, %) of the Level 1 PHYSIOPRINT model for the auditory, visual, and cognitive WL type and different combinations of the features.

	Visual WL		Auditory WL		Cognitive WL	
Feature space	REC	PREC	REC	PREC	REC	PREC
EEG-REF, no-history (NH)	72.4	73.6	68.8	68.2	55.9	57.3
EEG-REF, 5-second history (5H)	74.6	78.6	72.4	73.0	63.2	61.7
EEG-REF, EEG-DIFF, NH	79.7	79.1	72.2	76.9	62.2	64.7
EEG-REF, EEG-DIFF, 5H	88.9	86.4	78.6	83.2	73.8	75.2
EEG-REF, EEG-DIFF, ECG, NH	81.9	80.0	75.5	80.1	64.9	67.4
EEG-REF, EEG-DIFF, ECG, 5H	91.3	89.7	81.2	87.4	76.3	77.8
EEG-REF, EEG-DIFF, ECG, MF, NH	85.1	80.3	76.2	81.6	67.3	69.2
EEG-REF, EEG-DIFF, ECG, MF, 5H	**94.1**	**91.8**	**83.1**	**89.9**	**79.1**	**80.1**

3.2.2 Level 2 Classification Results

Given the aforementioned findings, the classification accuracy at Level 2 was assessed only for the combination of the all-inclusive feature space (EEG-REF, EEG-DIFF, ECG, and FM) and 5sec long feature vectors. For the visual workload tasks, the recall and precision were (REC/PREC): 78.8%/76.4% for the visual detection task and 93.1%/93.4% for the visual discrimination task. For the cognitive tasks, the recall and precision were (REC/PREC): 75.4%/74.1% for the easy/short digit sequences and 76.8%/77.5% for the long/difficult digit sequences.

3.3 Validation on the Driving Simulator Data

In this section, we first present performance results on the driving simulator, and then validation of the PHYSIOPRINT model on the physiological data recorded during driving simulation scenarios.

3.3.1 Driving Simulator Performance Results

In order to test the validity of our simulated driving task, we analyzed the subjects' performance on the driving simulator. There were a total of 780 discrete visual challenges (57 per subject across all six rides) with an equal split of expected reactions (260 button presses, 260 verbal acknowledgments and 260 silent responses); a total of 780 auditory challenges (with equal split among the expected responses); and a total of 360 cognitive challenges (3-digit numbers, half of them positive, half negative). In general, the subjects responded accurately to visual and auditory stimuli (94.1% accurate responses to auditory and 90.5% to visual challenges), but had more problems with the mathematical (cognitive) task, as the subject arrived upon the correct result at the end of the ride in only 41 out of 60 rides (68.3%). The majority of the reported results were, however, within ±10 of the correct result (57 out of 60, or 95%), which we interpreted as a sign that the subjects adequately engaged their cognitive resources and aimed at responding to the challenge (addition and subtraction of 3-digit numbers), even though their affinity/talent for math varied. In general, more errors were made during the two most difficult rides (92.6% average accuracy of responses to auditory, 87.4% to visual, and 55% to cognitive challenges), while the performance was notably better on the other four rides (96.1% for auditory, 92.7% for visual, and 75% for cognitive challenges). There was no significant difference in performance between the portions of the ride without the pedaling and those while the subjects had to pedal. Self-reports corresponded to the objective findings: the subjects mostly complained about the mathematical task and reported the two objectively most difficult rides to be significantly more challenging than the other four.

3.3.2 Classification of Driving Simulator Data with PHYSIOPRINT Workload Model

The PHYSIOPRINT classification accuracy was in general slightly lower on the data from the driving simulator study than it had been on the atomic tasks. Recall and precision (REC/PREC) during the periods with dominantly visual workload were 80.6% and 78.3% across all subjects and rides. Recall and precision during the periods with dominantly auditory workload were 71.5% and 73.6%, whereas recall and precision during the periods with dominantly cognitive workload were only 64.7% and 62.1%. When the PHYSIOPRINT classifier was applied to the subject's atomic tasks (i.e., VDET, VDI, FBDS, and ADET), accuracy increased (REC/PREC: 85.2%/78.3% for the VDET+VDI tasks, 74.9%/77.3% for the ADET task, and 76.3%/75.7% for the cognitive FBDS task). The classification accuracy was, on average, ~5% worse during the portions with the pedaling, which suggested that changes in heart rate and heart rate variability have relatively modest effects on this version of the classifier. The drop in performance could not be attributed to an increased level of noise in the signals (asserted by visual inspection). The modest increase in the classification accuracy when the classifier was applied to the atomic tasks on which the model was trained (VDET, VDI, ADET, and FDBS) suggested that the between-subject variability played a role, but was not the only or major reason for the drop in classification accuracy in the driving simulator study. It is possible that the overlap between the different workload types throughout the majority of the ride confused the classifier, and that the results could improve once more sophisticated mechanisms for detection and resolutions of such conflicts are built into the classifier.

4. SUMMARY AND OUTLOOK

The current study sought to develop a physiologically-based method for workload assessment applicable in the challenging automotive setting. We addressed this need by designing a comprehensive, sensitive, and multifaceted workload assessment tool that incorporates the already established theoretical workload framework that both: (1) covers the different types of workload employed in complex tasks such as driving, and (2) helps define the necessary atomic tasks for building the model. The experimental results suggested that the classifier benefits from combination of complementary input signals (EEG and ECG), better coverage of the scalp regions by an increased number of EEG channels, inclusion of concurrent physiological measurement of fatigue and alertness levels, and short-term signal history. We aimed to overcome the individual variability inherent in the physiological data by including the relative PSD variables in the feature vector. The generalization capability of the trained model was tested by using leave-one-subject-out cross-validation, as well as testing the model on the independent driving simulator dataset. The proposed method demonstrated that integration of physiological monitoring into automotive settings holds great promise for real time assessment of the driver's workload.

In the future, we plan to extend the model to cover all workload types (visual, auditory, cognitive, fine motor, gross motor, speech, and tactile) together with the corresponding workload intensity level subscales from the IMPRINT workload model. In order to achieve this, we need to design new atomic tasks carefully. We must also refine the existing tasks, especially the FMCT task that proved not ideal for representing pure fine motor activity. Additional physiologically based inputs, such as EOG, EMG, respiration, and stress levels will also be included to enable better insight into activations of different workload types. Alternative classification algorithms such as multi-label learning [21] will be evaluated to facilitate the process of resolving the conflicts between different workload types. The final global workload score will be a composite measure of all seven resource-specific workload type scores (analogous to the overall IMPRINT workload score). The weights will be designed in a way that also considers the influence of environmental factors, workload management strategies, and other individual traits and their effect on the overall engagement level of mental resources. The classifier will be validated on a larger sample of subjects performing a variety of tasks in both laboratory and real-life environments (i.e., real car).

The ultimate PHYSIOPRINT workload assessment tool is envisioned as a flexible software platform that consists of three main components: (1) an executable that runs on a dedicated local (client) machine to acquire multiple physiological signals from one or more subjects, processes them in real time, and determines global and resource-specific workload on a fine time scale; (2) a large server-based database of physiological signals acquired during relevant atomic tasks from a large number of subjects with different socio-demographic and other characteristics (e.g., degree of driving experience); and (3) a palette of real-time signal processing, feature extraction, and workload classification algorithms. The platform will support a number of recording devices from a wide range of vendors (via the appropriate device drivers), and enable visualization of the workload measures. The users will essentially be able to build their own workload assessment methods from the available building blocks of feature extraction methods and implemented classifiers. Initially, the database will include 100-150 subjects, but we envision that the database will continue to evolve as the community grows in the following years.

5. ACKNOWLEDGMENTS

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Cognitive Workload, Pupillary Response, and Driving: Custom Applications to Gather Pupillary Data

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ABSTRACT
Drivers often increase their cognitive workload (CW) through the use of in-vehicle technologies for communication, information, or entertainment. Previous work has attempted to measure CW in the driving domain through the use of performance, subjective, and physiological measures, however few have attempted to use pupillary response to estimate CW. The present work discusses a method of analyzing previously collected eye tracking data despite the eye tracking device's lack of pupil diameter (PD) analysis abilities and the validity of such a measure in the driving context. A custom made parser program was developed to gather the data from the eye tracking files and then put through another program to split and organize the data into the correct blocks and averages. The paper also addresses the difficulties in using such custom application for PD analysis as well as how to address issues of light induced pupillary response and a short discussion of standardization of pupillary response for CW in driving.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces And Presentation (e.g., HCI)**]: User Interfaces –graphical user interfaces (GUI), interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design; I.6.7 [**Simulation and Modeling**]: Simulation Support Systems

General Terms
Measurement, Reliability, Human Factors, Standardization, Verification.

Keywords
Driving, Cognitive Workload, Pupillary Response, Eye Tracking

1. INTRODUCTION
The definition of cognitive workload (CW), also referred to as cognitive demand or cognitive load, has long been debated in the psychological community. For the purpose of this paper CW will be defined similarly to how Mehler, Reimer, and Coughlin [1] defined cognitive demand based on De Warrd's [2] book: load or demand referring to the features of a task an individual performs and workload meaning the affect on the individual due to his or her performance of the task. An area where researchers focus heavily on CW within psychology is in that of driving, more specifically the area of driving and secondary tasks.

A prominent secondary task performed while driving is the use of in-vehicle technologies (IVTs). This use of IVTs while driving has been found to increase the CW of a driver [3]. This additional CW has been found to significantly decrease a driver's sensitivity to road events as well as lower their confidence in detection [4]. Furthermore, as the CW of a task increases, the risk of the user making an error before completing the task increases [5]. Within an attention-demanding task such as driving, increases in CW can make a big difference in safety. Measuring CW, whether during research or in real time, without any interaction from the driver, is an important area of research within the driving domain.

1.1 Measuring Cognitive Workload
Measuring CW can be achieved through subjective, performance, and physiological assessments [1,2,6]. Subjective measures, rating scales that convey the user's perception of the CW after each task, are an easy method of measuring workload. A common tool used for this measurement is the NASA-Task Load Index (TLX) assessment [8]. While this self-assessment tool provides highly validated measures of CW it is a subjective measure, which can be confounded, and it does not offer a real-time assessment without driver disruption, not ideal for measuring CW in a dynamic environment such as driving [1,7,9].

Since driving is most often performed in a dynamic environment, successful performance of the task necessitates driver attention. This highlights the need to measure CW in real-time without disrupting the user's performance [1]. To this end, unobtrusive measures such as driving performance or physiological responses can be used. In driving, performance measures are based on how well the user completes a particular part of the driving task (e.g., lane keeping, speed or speed variance, and steering wheel angle variance) [5]. While these performance measures may yield a correlation to CW, they also measure actual driving ability and can confound the data. Additionally, as every task measured in driving could be different, performance measures have to be tailored to each specific task, thus limiting the generalizability of the results [7].

Physiological measures can be used to interpret the user's cognitive state in real-time and unlike performance measures, do not have to be customized to each specific task, allowing for more flexibility and comparison across studies. Variations of these measures (e.g., heart rate, heart rate variability, respiration, eye position, and skin conductance) have been shown to correlate in an almost stepwise fashion with levels of induced cognitive load [1,7,10]. Mehler, Reimer, Coughlin and Dusek [10] found a correlation between heart rate and skin conductance and the introduction of secondary cognitive tasks, increasing the cognitive load of the drivers. However, while engaging in a secondary task, emotional and physical workload factors (body movement, temperature, stress, etc.) can also contribute to increases of these measures [7].

1.2 Pupil Diameter and Cognitive Workload

One physiological measure that has been found to react to changes in CW but not widely referred to in the driving domain is pupil diameter (PD), an effect also known as task evoked pupillary response (TEPR) [11,12]. This form of CW measurement is less intrusive than other physiological measures and could still provide an assessment in real-time. Pupillary response indicates levels of CW at each moment, communicates differences in processing load during different tasks, and conveys variance within the same task [13]. While showing that PD varies with emotional stimulation, Partala and Surakka [14] noted the difficulty of voluntarily varying PD as an advantage of the measure.

Pupil dilations occur as soon as it processes load and quickly returns to baseline state thus creating a sensitive measure of CW [9,5]. Palinko, Kun, Shyrokv, and Heeman [5] observed the dilation and contraction of pupils as driver's attention was divided by a word game. PD was found to increase as the driver thought of a word, peaked when the word was uttered, and gradually decreased before the next word. This indicated an increase in CW as words were recalled which were similar to results of Granholm, Asarnow, Sarkin, and Dykes [15] in a digit span recall task. They also found that PD increased as processing load fell below the resource limits of the cognitive task, was stationary once processing load was reached, and decreased when the user disengaged active processing, displaying that PD responds to varying levels of processing load [15].

Iqbal, Zheng, and Bailey [9] measured percentage change in PD (PCPS) by subtracting the baseline PD from the size at each task and dividing the result by the baseline size. The authors then averaged PCPS of participants performing visual tasks on the computer and results showed a significant difference in average PCPS between easier and more complex tasks. PD was also found to correlate with changes in cognitive load that varied over hierarchical tasks, indicating its validity as a measure for CW. Palinko et al. [5] also looked at mean PD and mean PD change rate when focusing on CW changes, results suggesting the measures' usefulness.

The application of PD has been attempted and seems to hold up in the driving environment as well. Recarte and Nunes [16] found that when participants were performing a secondary task while driving they had significantly larger PDs than when performing only the driving task. In a later experiment on detecting targets while performing mental tasks, Recarte and Nunes [17] noted lower percentages of detected targets causing poorer performance as a result of an increase of mental tasks and participants' workload. This increased workload while performing tasks was also shown by pupillary dilations. Similar results were seen in a simulation study where the driver performed a lane-changing task and a visual search task [18]. As the visual task was introduced, driving performance decreased and PD increased. This correspondence between performance and PD has been attributed to their convergence, but assessing using PD still creates a finer form of measurement of CW [5].

While research in this domain has included the use of TEPR to estimate CW, some researchers' technologies do not allow for access to the data required or are not currently supporting this application of the devices used. In order to increase the availability of this data and allow for researchers to use TEPR as another tool for measuring cognitive load the process of gathering and analyzing the data must be more easily completed. The current paper discusses the use of Tobii mobile eye trackers to measure CW through PD, including the creation of necessary programs to get the data from the eye trackers to an analyzable state. The paper also compares the results of the PD differences between conditions to differences seen in subjective workload measures in the same study. The data used in this report is taken from a study previously analyzed, written up, and accepted for publishing [19]. However, at the time of the research design and analysis, PD data was not an available measure due to the lack of these programs and was therefore also not gathered in a way to be analyzed specifically in this way. This lack of planning to analyze the data may have created some of the noise seen in the analysis and is discussed along with the support found for the application of this technique in future work.

2. METHODS

2.1 Participants

The participants in this analysis were 24 students at a large research university in the United States. All participants had valid drivers licenses and had normal or corrected to normal hearing and vision. The 17 males and 7 females were an average of 20.17 years old and had a mean of 4.54 years driving experience. Not all of the participants included in the initial study are included in the current analysis due to technical issues with some data files.

2.2 Apparatus and Procedure

To see an extended description of the apparatus and procedure of the study this data was taken from see Gable, Walker, Moses and Chitloor [19]. In short, participants were asked to wear Tobii eye tracking glasses while performing a dual task situation by driving the lane change task and executing a search task on a touchscreen smartphone. The participants completed 6 conditions during the experiment, 1 being a control of only performing the driving task and 5 dual task conditions. Of the 5 dual task conditions 4 had auditory cues and 1 was performed with no auditory cues.

2.3 Design and Analysis

The analysis of the data in the current report as compared to previously collected CW data is the focus of this paper. During the initial stages of the previous study and during the analysis and write-up of the data, the PD measurements were not accessible using the software available to the researchers. Recently, however, we created two custom programs in our lab that made the pupil data obtainable.

Of the two programs used in the analysis, one was created to pull the data out of the native Tobii files and the other to separate the data into blocks and give averages. First the program called TobiiReader, written in C#, extracts the values for each frame for all metrics from the proprietary Tobii projects (".gfp"s) and outputs these into tab-separated documents. This document then contains every frame value for all possible values from the eye trackers, including any frames where the eye trackers could not read the pupil due to the either tracking error or participants looking outside of the rim of the glasses. In this instance the file reports the pupillary response as 0, which can skew the data and should be addressed by anyone recreating this process. A second, command line application that was written in Ruby, called TobiiParser is then used to interpret the PD by finding averages over specific ranges of time. These time ranges are gathered by hand based on the timestamps separating blocks or conditions in Tobii Studio and input into the command line. TobiiParser then outputs the average PD with and without missing values, as well the number of missing values. The program could be modified to output other information if needed.

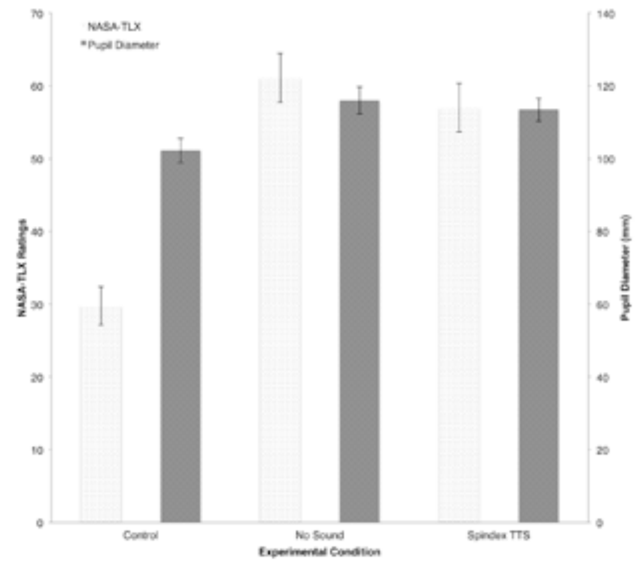

Figure 1. A bar chart displaying the mean TLX ratings and PDs of the three driving conditions: driving only, driving + search task no sound, and driving + search task spindex TTS.

This data was then entered into a spreadsheet along with the previously collected TLX ratings for the same participants for each of the blocks. Instead of comparing all of the conditions from the original study it was decided to only compare 3 of the conditions in an effort to save time while still examining the abilities of the eye trackers to measure changes in PD. The conditions that were chosen included: a control of only performing the driving task, the condition that according the TLX created the least amount of cognitive load; driving plus the secondary task with no sound, the condition that created the highest level of cognitive load according to TLX; and driving while performing the dual task with the auditory cue of spindex TTS (an advanced auditory cue, see [19] for more information), the cue that seemed to diminish the cognitive load on the drivers the most out of all the dual task conditions.

3. RESULTS

Figure 1 displays the mean combined TLX ratings and PDs for each of the three experimental conditions included in this analysis. A similar trend can be seen between the two measures for the three conditions, with the control condition having a much lower value and then increasing for the no sound search task condition before slightly decreasing in the audio condition of spindex TTS. In an effort to investigate this trend a one-tailed Pearson's r correlation test was performed, the scatterplot of which can be seen in Figure 2. Results of the test showed a moderate positive correlation between the TLX ratings and the PD (mm), $r = 0.339$, $n = 72$, $p = 0.002$.

Paired t-tests showed that the control condition had significantly lower TLX ratings ($M = 29.8$, $SD= 16.5$) than either the no sound condition ($M = 61.1$, $SD= 18.0$), $t(23) = -8.22$, $p < .001$, and the spindex TTS condition ($M = 57.0$, $SD= 15.5$), $t(23) = -9.13$, $p < .001$. No significant difference was seen between the two search conditions. Similar results were found for the PD measure with the control condition having significantly lower average PD ($M = 102.2$, $SD= 13.0$) than the no sound condition ($M = 116.0$, $SD= 16.5$), $t(23) = -10.28$, $p < .001$, and the spindex TTS condition ($M = 113.4$, $SD= 16.2$), $t(23) = -6.20$, $p < .001$, with no significant difference between the search conditions.

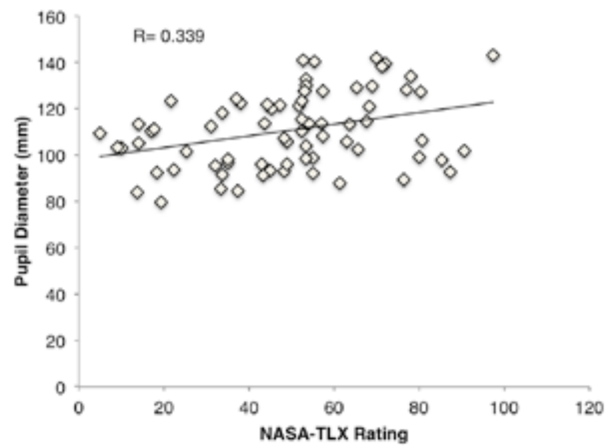

Figure 2. A scatterplot displaying PD and corresponding TLX ratings for all the participants in the three conditions.

4. DISCUSSION

The creation of these custom applications will allow for the measurement of pupillary response in future work and could easily be shared with other academics who have encountered the same issues with this software lacking in PD analysis abilities. The lack of differences between the two search conditions for pupil size was possibly due to a lack of trials since no difference was seen with TLX ratings, but not at the fault of PD as a measure of CW. While the correlation between the TLX and PD was only moderate, it does give merit to using this method for estimating CW, or using the measure along with other physiological, subjective, and performance measures in a multivariate analysis. The lack of a stronger correlation could be affected by multiple factors, particularly of interest being the issue of looking between the driving and secondary task, causing differences in luminance.

Kun, Palinko, and Razumenić [12] reviewed this topic of luminance and the obscuring effect it can have on data when measuring CW through pupillary response. They discuss that while CW can have an affect of pupillary dilation, the major contributor to the size of an individual's pupil is the pupillary light reflex (PLR). This reflex can confound data if luminance in part of a scenario is darker than others when using either a simulator or an on road study. Additionally, and particularly important in the current analysis, when participants are interacting with secondary tasks while driving their visual attention can move between the screen or road area, and the IVT. This visual movement from very separate luminance areas of outside and inside the vehicle or simulated cab could have large impacts on the pupillary response. Kun, Palinko, and Razumenić [12] discuss a possible way of addressing this issue through the use of a weighting function. Another option given by the authors is creating a scenario with minimal changes in target luminance, however this could be difficult to do when a study involves IVTs.

Although these custom applications work, it would be to our advantage to continue to make the process more efficient. The need to use multiple applications to get the data into the correct format is time consuming. Through merging the applications this would decrease the complexity of the process and hopefully make the process faster as well. The ability to input time blocks through some sort of script would also be a helpful addition to the application, as in its current form the process must be done one block at a time. Additionally the two programs used in this process run on different operating systems (Windows and Macintosh) so both types are necessary to complete the process.

Overall this expansion in abilities will allow for more measures of CW and offer variables to researchers where they were not possible before. However, before using these applications or any like them to analyze previous eye tracking data, the effect of not planning a study to measure pupillary response data should be considered due to the effects of PLR discussed above. If possible the research using this type of data and these custom applications should consider the effects of PLR and plan a way to gather the necessary data to create a weighting function. The next study investigating the effectiveness of the Tobii eye trackers and these custom applications will need to address this confounding factor to look at the relationship of pupillary response and TLX with less noise. Additionally researchers that would like access to these applications should understand the applications are not yet refined to a commercial level and the analysis remains time consuming.

While this paper does not directly discuss any standards, this is an important factor to consider when investigating pupillary response and CW. In its entirety, the measurement of driving distraction has a wide range of terms used for similar constructs and forms of measurement to estimate CW, and pupillary response within CW is no different. However, pupillary response along with some of the physiological measures of CW are still in the beginning stages of becoming a mainstream form of CW measurement due to technologies becoming more affordable and research supporting their application more widely available. As these somewhat recent measures of CW grow, authors should be able to find a way to know the correct way of referring to constructs and measuring these physiological factors. This need could be addressed through the community interested and active in this area of research to come together and decide what measures of CW will be used in which way and how the data should be gathered, organized (such as the issue with the missing frames in our data or the weighting function discussed by Kun et al., [12]), and reported. Whether the workshop on cognitive load should push this effort forward through the creation of an annual report or leave the standards papers to be written through government funded groups such as NHTSA is another decision. The decision however, must be made before it is too late so as to allow enough time to go by before the standards are released and new researchers in the area begin performing research and writing it up based on literature not addressing or using these standards.

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The Car That Cares: Introducing an in-vehicle ambient light display to reduce cognitive load

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ABSTRACT
Driving is a cognitively demanding task. Hence, it is necessary to keep the driver's cognitive load in mind while designing new assistant systems. In this paper, we will present first goals of the recently started project "The Car That Cares". One goal is to keep the driver's workload low by adapting the information display to the driver's abilities and available cognitive resources. We want to find out if peripheral vision is a less demanded resource while driving and therefore propose ambient light as an alternative modality for information presentation. Furthermore, we present our approach to measure the driver's cognitive load using *functional Near-Infrared Spectroscopy (fNIRS)* and other techniques.

Categories and Subject Descriptors
H.5.m [**INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)**]: MISCELLANEOUS

General Terms
Design; Human Factors; Measurement.

Keywords
peripheral interaction; ambient light; cognitive load; brain imaging; fNIRS.

1. INTRODUCTION
One of the research objectives of our recently started project *The Car That Cares (CtC)* is to find how in-vehicle assistant systems can adapt to the driver's state (e.g. health or cognitive state). In the process, we are looking into alternatives to existing assistant systems and interactions between driver and vehicle as well as into how to measure the driver's state.

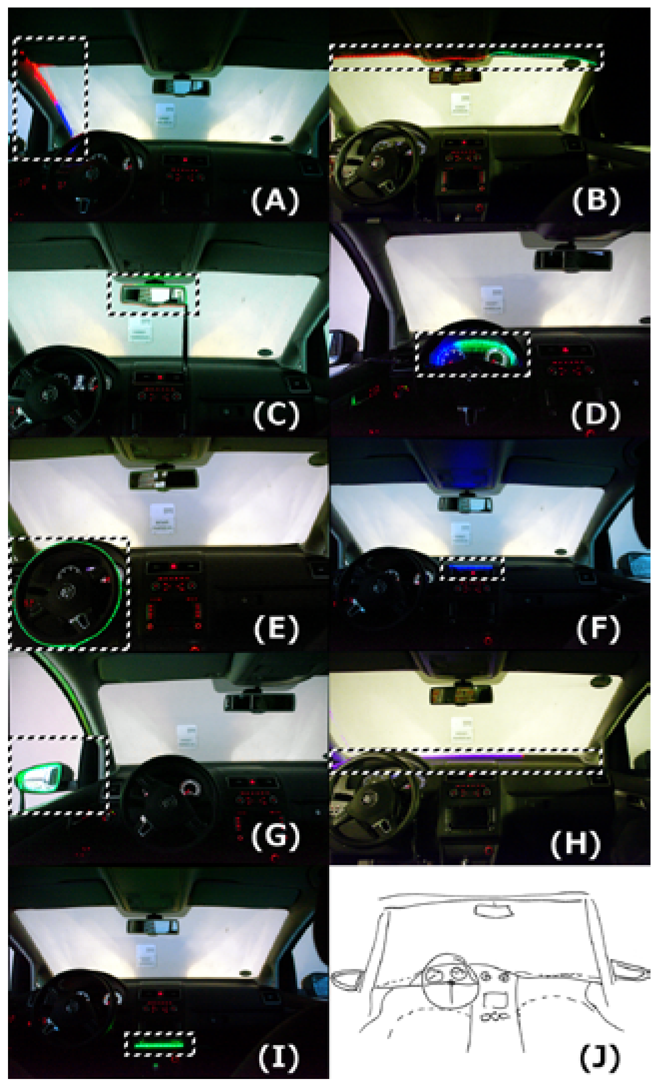

Figure 1: (A-I) show different locations for the ambient light display. (J) shows the image where participants could sketch their ideas.

Coughlin et al. tried to increase safety by alerting or calming the driver depending on his or her arousal [2]. They studied methods to assess the driver's state, such as measuring skin conductance or eye movement. In addition, they motivated concepts for displaying information, including a light display. We want to manage the driver's cognitive load by adapting the interface to environmental conditions as well as the abilities and current cognitive load of a driver. We argue that the load is reduced if information is presented via a less demanded resource, following Wickens' multiple resources theory [22].

Many modalities addressing different cognitive resources have been introduced to the automotive domain. For example, navigation devices using vibro-tactile, visual or auditory cues (e.g. [8, 9, 10]). In addition, warning systems using visual icons, haptic feedback or auditory signals alone or in combination were tested (e.g. [1, 7]). As discussed in [22], peripheral vision and foveal vision demand different mental resources. This makes peripheral vision an interesting alternative. Our previous work (e.g. [14]) has shown that ambient light can be utilized to present information in other domains. Laquai et al. introduced an in-vehicle light display to keep safe speed [11].

In the following, we will discuss how we plan to find a suitable position of an in-vehicle ambient light display. Furthermore, we will introduce designs for our evaluations. In addition, we will present how we plan to measure the cognitive state of a driver using different techniques. Thereby, we will focus on *functional Near-Infrared Spectroscopy (fNIRS)*.

2. POSITIONING THE LIGHT DISPLAY

Tönnis et al. gave guidelines on where to place displays in cars amongst others [20]. However, their guidelines for visual displays focus on displays that need focused attention. Complementing this, we want to explore the possible locations of an ambient light display, which is seen peripherally.

Following a user-centred process, we performed a brainstorming session with five drivers and identified several locations for light displays. In a recently conducted online-survey, we presented nine of these locations to participants and asked them to rate the locations. Figure 1 shows these locations. At the end of the survey, participants could propose own ideas of an ideal position. Furthermore, they were able to give additional feedback.

Taking this approach enables us to reach more participants and thereby using fewer resources compared to inviting drivers to a lab study and presenting different implementations of real prototypes. However, this approach must not replace follow-up studies using hardware prototypes, where effects of different locations on the driver's perception are measured.

First results show that most participants preferred the dashboard as location for the light display as shown in Figure 2. Participants also rated the dashboard to be the most perceptible location. A detailed discussion of this survey will follow in another work, as the results are yet to be analysed. After the analysis, we will be able to limit the number of needed prototypes for the evaluation in more realistic conditions.

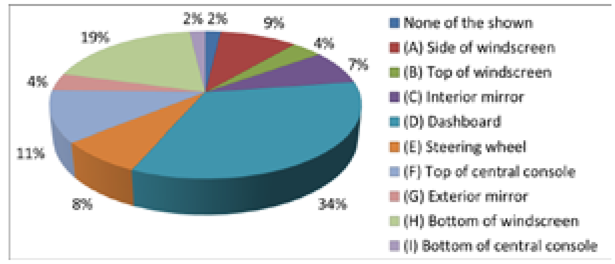

Figure 2: Out of 58 participants, 5 did not choose a favourite location for a light display. 34% of the remainder chose *At the dashboard*, while 2% chose the option *None of the shown*. *At the bottom of the central console* is the least preferred location (2%).

3. DESIGN OF THE EVALUATIONS

In the future, our display should assist the driver in all safety relevant driving situations. However, we decided to investigate one scenario as a starting point. The lane-change test as for example described in [18] is well documented and therefore publicly replicable. For our evaluations, we adapt this test by adding other road users and measure how drivers responded using different lane-change support systems, such as the light display. In this way, we are able to additionally measure the driver's decisions depending on the situation.

An example for a situation within our proposed scenario "lane change and overtaking manoeuvre" is illustrated in Figure 3: If the red car wants to overtake the bus, it needs to change the lane. The situation may be dangerous, if the driver is not aware of the blue car behind. To alleviate the problem, our display will shift the attention of the driver to if the blue car has not been seen. A possible behaviour for a light display in that situation may be a red flashing point of light that moves from the centre of view towards the left sight of the driver to shift his or her attention. However, this is just an example and may not be suitable at all, as finding possible behaviours is one aim of our future research. Further, we need to assess the driving situation and the driver's state before selecting an appropriate modality like ambient light, to display information to the driver if needed.

For our first evaluation, we plan to create a few prototypes of light displays at different locations in a driving simulator. The primary task of a driver is to overtake other cars. Concurrently, a driver needs to judge if it is possible to overtake based on his assessment of the current situation. We will measure the cognitive load of a driver performing these tasks in a baseline condition (no assistance) and different

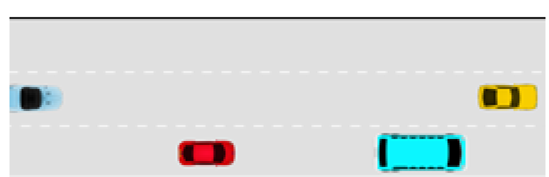

Figure 3: Example situation: The driver of the red car wants to overtake the bus, but needs to consider the blue and yellow car.

prototypes of the ambient light display. In doing so, we plan to answer the following questions: Can *fNIRS* be used to assess cognitive load? Does the location of a light display, regardless of its behaviour, significantly affect the cognitive load? In the future, we plan to use the same approach to evaluate different behaviours and other modalities.

4. COGNITIVE LOAD MEASUREMENT

In this section, we propose our approach on different techniques to measure a driver's cognitive load. We will further describe how we plan to find out if *fNIRS* can be used to monitor the driver's state (including load) in real-time.

4.1 Self-assessment

In previous works, we successfully used the *NASA Task Load Index (NASA-TLX)* as a self-assessment technique. The NASA-TLX is one of many post-hoc techniques that use questionnaires and are described in [5]. The main benefits of questionnaires are that it is easy to collect and analyse the data. However, it is not possible to gather the data during the tasks which may distort the results. In addition, self-assessment techniques collect the subjective impressions of drivers which may differ from their actual cognitive load. Despite that, NASA-TLX is often used in other studies. Hence, using it as additional measure will enable us to compare our results to related work more easily. Still, we need a real-time measurement and more accuracy.

4.2 Measuring the driver's performance

Another way to evaluate cognitive load is to measure the performance of a driver (e.g. braking response times) when solving secondary tasks that demand cognitive resources (e.g. setting up a navigation device). This way it is possible to measure the impact on cognitive load for different tasks, assuming that driving performance is related to the cognitive load. A tertiary task (e.g. n-back) can be added to increase the load and compare the impact on it for different secondary tasks at a higher level of cognitive workload. However, using this technique will only provide insights to the performance of a user at different levels of load and not on the cognitive load itself. Furthermore, it is highly dependent on the design of the tasks. On the other hand, this technique can be used to find correlations between cognitive load and physiological parameters as it was for example done by Reimer et al. in [19]. In our scenario, the driver's secondary task is to judge if it is possible to overtake based on his assessment of the current situation with the help of our light display, compared to judging without assistance.

As described, self-assessment and performance-based measurements can be used during evaluation. Nevertheless, our multimodal display should eventually be able to adapt to the driver's state, including cognitive load, in real-time. Measuring physiological characteristics, such as pupillometry (e.g. [17]), heart rate or skin conductance (e.g. [19]) can be used to assess the cognitive workload in real-time, but is still restricted in its validity, as changes in those parameters are only indicators for cognitive load. The origin of cognitive load occurs in the brain. Hence, using brain imaging to study cognitive load is a direct measurement criteria. There have been studies where brain imaging has been used to assess cognitive load [6, 13] and we decided to stick with

Figure 4: Measurement Cap used with the *fNIRS* system. Source: [16].

this approach. Later, we may integrate other physiological parameters to increase the accuracy and robustness of the assessment.

4.3 Measuring cognitive load using fNIRS

In the project CtC, we use the *functional Near-Infrared Spectroscopy (fNIRS)* system to study brain activity. The *fNIRS* system measures the absorption changes on sub-surface tissues of the brain. Low-energy optical radiation is transmitted using light sources and the local concentration changes of oxy-hemoglobin and deoxy-hemoglobin is measured using optical detectors which can be correlated as a function of brain activity [15]. Figure 4 shows a set-up of the source-detector pattern on the measurement cap used in *fNIRS* analysis. We use this technique to measure neurophysiologic activities in the left dorsolateral prefrontal cortex (DLPFC) and right ventrolateral prefrontal cortex (VLPFC) as these areas correspond to the cognitive areas of the brain [13].

fNIRS has some advantages over other techniques like functional magnetic resonance imaging (fMRI [21, 4]), electroencephalography (EEG) or magnetoencephalography (MEG). *fNIRS* measures both oxy- and deoxy- Hb concentrations and this extra dimension helps in motion artifact removal [3]. fMRI requires a strong magnet and produces loud noises. The subject is constrained to a supine position during scanning making it unsuitable to measure brain activity under normal working conditions. EEG cannot really differentiate between brain areas and takes much longer to set-up compared to *fNIRS* [12]. MEG provides better spatial resolution compared to EEG but it is highly sensitive to head movements just like fMRI.

As mentioned in section 2, we plan to implement prototypes of different light displays at different locations (peripheral visual feedback). We plan to measure the brain activity for different locations and to compare brain activation patterns to reference measurements obtained while subjects performed a low visual cognitive workload driving task to assess cognitive work using brain activation measures [6]. This data should make it possible to judge the workload induced by the location of the light in order to select the locations that induce least amount of cognitive workload. Based on this analysis, we will be able to compare different light patterns at a specific location using the same technique. We also intend to incorporate other multimodal displays like audio, audio-tactile or vibro-tactile cues in the future.

5. CONCLUSION

We presented our first goals in the project "The Car That Cares". Following Wickens' multiple resource theory ([22]), we argue that it is possible to reduce the cognitive load by displaying information to a less demanded cognitive resource. As a first step towards an adapting multimodal display, we investigate if ambient light is a modality that can be used to send information to a driver. Therefore, we asked drivers as to which location of an ambient light display would be suitable and plan to evaluate the influence on cognitive load for a subset of these locations.

We plan to use an adapted lane-change task in a driving simulator as scenario for our evaluations. In addition to the driver's performance, we will measure the cognitive load using NASA-TLX and *fNIRS*. NASA-TLX is thereby used to evaluate the validity of the assessed load using *fNIRS*. Later, other physiological measurements may be added to receive more reliable results or increase the driver's acceptance.

Another short-term goal is to find a location for the ambient light display and evaluate different patterns of lights. Later, we would like to look into other modalities and create a multimodal display. Eventually, this display should be able to adapt to the driver's state and divert his or her attention to unnoticed dangers if needed.

6. ACKNOWLEDGMENTS

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Cognitive Load Impairs Experienced Drivers' Judgments on Self-Reported Driving Superiority

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ABSTRACT

It seems reasonable that sooner or later, constantly overestimating one's driving skills may promote inappropriate driving and misjudgments of critical situations. However, it is very common for drivers to succumb to a self-perception bias by evaluating their own driving skills to be superior than the average [2]. A web-based between-subjects experiment was conducted to analyze drivers' inability toward accurate self-assessments. Using Cognitive Load Theory (CLT), we assessed whether this bias is further amplified when conscious deliberation is unavailable. First, the results clearly replicated the bias. Second, there was no difference between drivers' self-assessments under load and without load, although it is suggested that automatic processing promotes self-assessments which are even more favorable. Third, there was a significant effect of load on how experienced drivers perceived their superiority judgments. Those under load thought they rated their own abilities less superior to the average driver, while in fact their ratings were in line with the overall bias. This holds only for those driving at least the average traveling distance in Germany of approximately 1000 kilometres per month.

Categories and Subject Descriptors

J.4 [**Social and Behavioral Sciences**]: Psychology

Keywords

Cognitive load, Driving skills, Self-evaluation, Web-based experiment

1. INTRODUCTION

Cognitive load plays an important role during vehicle control, there are numerous experiments highlighting this relationship. In a broader sense, the implications of CLT on human behavior can be applied to hypothesize about load effects on driving that currently lie beyond driving research interests. Those potential load effects might just as well be studied in a controlled driving environment. On top of load effects on driving as depicted by experimental driving research (e.g. [3], [7]), there is a large amount of unexplored findings, especially in the social psychology and cognitive science literature. Many of those findings show that CLT can be applied to driving beyond dual-task driving scenarios in order to paint a more thorough picture of how cognitive load not only directly affects driving performance, but also modulates related processes such as self-perception, prospective memory, and stereotypes. As a research paradigm, CLT can be a useful source of how cognitive processes that people seamlessly rely on are affected when their minds are busy. Interestingly, some of these processes are connected to driving. This is because driving involves an interplay of many bodily, cognitive, and social processes (e.g. motor control, experiencing distress, attention allocation between in-vehicle elements and objects outside the vehicle, multi-tasking, interacting with passengers and other drivers, empathy, performing hostile and aggressive driving). Other than driving, there are probably only few highly widespread types of human-machine interaction covering this many elements relevant for research. In this paper, we focused on how drivers assess their own driving skills under load. We present results of a web-based experiment and discuss the role of driving experience for this self-evaluation.

2. RELATED WORK

Put in general words, the benefits of CLT are based on the effects arising from a state of scant cognitive resources. In this state, conscious effortful thinking cannot be maintained. There are manifold consequences of cognitive load on different types of information processing. For example, under load, people are more likely to apply previously activated stereotypes [4] and to forget actions they have planned in the past because prospective memory is depleted [8]. Cognitive load furthermore modulates the sense of agency, that is, an individual's ability to identify effects caused by the self. Under load, this usually basic process of connecting a self-initiated cause and the related effect is inhibited [5]. Finally, people evaluate themselves more positively under load because in contrast to the complex process of self-verification (does the stimulus confirm my self-opinion?), self-enhancement (does the stimulus put me in a favorable light?) is performed automatically [12]. Swann et al. [12] argue that when resources are depleted, certain representations of self cannot be accessed from memory and compared with self-relevant stimuli. Furthermore, the positive automatic self is highly practiced, for example through repetition over the whole lifetime [10]. To what extent are these phenomena possibly linked to behaviors which directly or indirectly affect driving related processes? In other words, why does cognitive load as a concept warrant more attention within the driving research domain?

Driving and Stereotypes. It is safe to say that for as long as vehicles will be controlled by humans, driver aggression will be an issue for road safety. Hostile and dangerous behaviors like honking and running red lights need to be explained by various reasons, such as personality, culture, context, and so forth [11]. Interestingly, some determinants of driver aggression can be linked to cognitive load. In the 1970s, hostile behaviors against female drivers were recognized to follow from a specific stereotype against them [1]. Drivers applying this stereotype, that is, letting their judgment and behavior be influenced by it, will honk at female drivers more often [1]. The overall tendency, then, to apply this or any other stereotype making assumptions about the driving performance of a specific group of people (e.g. elderly or novice drivers) is facilitated by cognitive load [4]. However, the stereotype must have been activated first. In fact, the effect of cognitive load on the imminent role of stereotypes is two-sided, as Gilbert and Hixon aptly explain [4], because on the one hand, load facilitates the application of a stereotype in terms of stereotype-conforming responses; on the other hand, though, load decreases the preceding activation of this stereotype. Generally, stereotype activation can be regarded as "finding a tool in the cognitive toolbox" whereas application can be thought of as "using the tool once it has been found" [p. 512]. Thus, performing under load increases the likelihood that a driver does not see a female driver in traffic and instead, just a driver.

Driving and Prospective Memory. Completing intended actions in the future is guaranteed by prospective memory. A depleted prospective memory causes the forgetting of important actions, for example taking the right freeway exit. Marsh and Hicks [8] found that attention-demanding tasks play a key role. More specifically, inhibition was a function of simultaneous planning and careful performance monitoring. When the executive functions in charge of switching attention between planning and monitoring were heavily loaded, prospective memory performance decreased. The same decrement occurred when a demanding visuospatial task was involved. Accordingly, prospective memory decrements are to be expected when driving is no longer part of the set of routine behaviors because of environmental constraints, and when a planning task must be maintained simultaneously, for example wayfinding. Furthermore, the involvement of critical visuospatial tasks such as parking may also increase the likelihood of forgetting to remember.

Driving and Agency. Being a good driver obviously requires good driving performance. Knowing to be a good driver requires the right perspective on events that occur during driving, for example whether dangerous situations were caused by the driver or not. Accordingly, people can only conclude they are (not) particularly good at driving if their sense of agency is not disturbed. Under load, there are not enough resources for accurately comparing the predicted effect with the actually occurring effect, because mental model construction for the prediction fails [5]. If the sense of agency is impaired as is the case under load, drivers are more likely to take credit on the road for outcomes that, in fact, were due to other drivers' actions or mere luck. Conversely, they might attribute critical situations they can be held responsible for to external sources, effectively neglecting their own responsibility.

Self-Evaluation of Driving Skills. Last but not least, relying on biased overly positive attitudes regarding one's driving skills may increase the likelihood of inappropriate driving. It is this aspect, the way how drivers usually assess their own abilities, that we focus on. The perceived superiority is strong, it holds for a wide range of driving skills, and it comes closer to a "positive-self" than a "negative-other" bias [9]. While it is still unanswered whether drivers' self-perceptions have an actual effect on relevant outcome variables like risk-taking and road safety ([2]), this may be easier to unveil if we can explore whether automatic processing modulates the perceived self-superiority. We expect an amplification effect because automatic processing predicts the need for self-enhancement in terms of choosing favorable evaluators and feedback [12]. Moreover, unconscious self-reflection, also called implicit self-esteem, is generally positive and corresponds to explicit self-evaluations, but only under time pressure or reduced cognitive resources [6].

Taken as a whole, load effects on these different aspects indicate how load may affect driving in terms of how drivers respond to external stimuli, how they process information, and how information is stored or accessed. Of course, this holds for other forms of human-machine interaction as well, but driving We thus hypothesize that when drivers are put under load and deliberate processing cannot be maintained, self-evaluations will be more favorable than in the absence of load.

3. METHOD

We conducted a web-based experiment in which we asked subjects to evaluate their own driving skills as well as their opinion on the average driver's skills on various dimensions. Half of them answered the questions while being deprived of cognitive resources (load condition); the other half answered the same questions under normal conditions (no-load condition).

The experiment consisted of four short blocks. (A) First, subjects were asked to enter their average driving distance per month in kilometres. (B) They then were required to rate themselves and (C) the average driver along 18 driving tasks, taken from McKenna et al. [9] and translated into German.[1] (D) Last, they were asked to indicate to what extent they thought they rated themselves worse or better than the average driver in the previous step and, in their eyes, how positive other people rate themselves compared

[1]The tasks were: Driving at appropriate speed for conditions, Paying attention to road signs, Changing driving to suit wet/icy/foggy conditions, Judging stopping distances for appropriate speeds and conditions, Attention to and awareness of other vehicles, Judging correct speed for bends/corners, Leaving motorways, Hill starts, Driving in busy town traffic, Changing lanes on motorways, Moving onto motorways, Parking, Judging the width of vehicles, Three point turns, Overtaking, and Changing traffic lanes.

to the average. All ratings were done using 7-point Likert scales.

The manipulation required subjects in the load condition to rehearse an 8-digit number while answering the questions. They were given 60 seconds for learning. This rather basic manipulation was successfully used in previous experiments to induce cognitive load (e.g. [4] [12]). After subjects were finished with the questionnaires, load condition subjects were asked to enter the number they had been rehearsing.

One hundred and seven subjects with a driver's license for automobiles participated in the experiment. We excluded those with a self-reported average driving distance of 0 kilometres per month from the dataset. We furthermore excluded one subject who indicated that he was substantially distracted during the experiment. We also excluded those with more than three errors in the rehearsing task. Thus, a total of 95 subjects remained in the dataset (32 females, 63 males). 45 were in the load condition, 50 in the no-load condition. Mean age of the sample was 29.56 years (SD = 7.38). On average, subjects drove 740.15 km per month (SD = 1459.12).

4. RESULTS

Paired-samples t-tests comparing self-evaluations and evaluations of the average driver once more replicated the fact that drivers perceive almost each and every aspect of their driving abilities as superior. Of the 18 items, only 2 ('Reversing' and 'Navigating and driving in unfamiliar area') did not yield significant differences. With respect to the 16 other items, subjects thought they generally perform these tasks better than the average. For one of those items, $p < .05$, otherwise $.001 < p < .01$.[2]

Independent-samples t-tests comparing self-evaluations of load and no-load subjects did not yield any significant results, $.15 < p < .98$ for all 18 items. Thus the hypothesis stating depleted cognitive resources would lead to a stronger self-reported superiority was not supported. A closer look at the data in the no-load condition which, according to our hypothesis, had to be surpassed in the load condition, reveals that for 15 items, the means were considerably large, $5.00 < M < 6.26$ ($.83 < SD < 1.48$). Next, we looked at how accurate subjects under load reflected their ratings and whether they assumed self-reported superiority for other drivers as well. For both aspects we found no differences, $.38 < p < .39$.

In the last step we focused on those with a quantitative driving experience at average level or higher. We therefore excluded all subjects with a monthly average driving distance below the average value recently found in the German Mobility Panel: 1055 km/month.[3] Nine subjects remained in the load condition, 10 in the no-load condition. The average driving distance in this sub-sample was 2336.84 km/month ($SD = 2707.49$). The mean age grew slightly higher compared to the total sample ($M = 33.53$, $SD = 6.11$). There were 2 females and 17 males.

Again, there were no significant differences between both conditions, $.05 < p < .95$ for all 18 items. However, subjects under load ($M = 5.22$, $SD = .97$) now thought their previous self-evaluations were less above average compared to subjects withoud load ($M = 6.30$, $SD = .68$), $t(17) = 2.83$, $p < .05$, although in fact, there was no difference for superiority between both conditions since the hypothesis was not supported.

5. DISCUSSION

We attempted to show that drivers deprived of cognitive resources would in an offline situation exaggerate their favorable self-evaluations because automatic self-evaluations are generally more positive. Upon success, it would have been interesting to analyze which forms of load (working memory, perceptual, communicative) affect the current, not overall self-evaluation in an online situation. We chose an offline setting because our concern was to explore the potential of two inter-related aspects for driving research: A feasible methodology using a basic, low-effort load manipulation, and the diverse responses under depleted cognitive resources. However, with respect to automatic versus controlled self-evaluations, there was not much left to disentangle. Even when drivers had sufficient resources to correct overly positive self-evaluations along the presented tasks, the self-evaluations were still very positive. There was simply no more potential for an increase in the load condition.

Instead, we found that in this offline situation, some drivers under load were less aware of how superior they actually evaluated their own abilities. Although load did not affect actual evaluations, it had an effect on meta-evaluations for those driving as much as or more than the average German driver. While this result should be explored further with a larger sample, it indicates how cognitive load modulates the assessment of driving skills if driving is performed with certain experience. Acquiring experience in an activity means to perform it more automatic and mindless. It becomes an activity that requires abilities one does no longer cast doubt on. Experienced drivers may lose practice in effortfully reconsidering their self-image, especially when they rarely encounter critical situations. Under load, they are deprived of the possibility to accurately reflect upon their evaluations. It becomes too effortful to align their evaluations to reality. For less experienced drivers, this effort may be smaller. More data is needed to support this possible explanation. Furthermore, future studies need to clarify whether the difference in meta-evaluations for experienced drivers under load versus not under load are caused by idiosyncrasies of driving, or whether there is a general underlying tendency not particularly related to driving. This can be accomplished by a comparison with self-evaluations of other skills.

The result suggests there may be a large amount of drivers which, in certain situations, become less aware of the fact that they are likely to overestimate their own abilities. Even if we assume this erroneous meta-evaluation has no effect

[2]Since this finding is not very surprising and detailed information is not of value here, the specific dimensions will not be mentioned.

[3]The panel is produced on order of The German Federal Ministry of Transport, Building and Urban Development. The document for the 2011/2012 version can be found at this location: http://mobilitaetspanel.ifv.uni-karlsruhe.de/de/downloads/mop-berichte/index.html (German version only)

on actual driving because the exaggerated self-evaluations also might not, it would be hard to ignore how experienced drivers could sometimes fail to realize their self-view as being highly biased. Generally, succumbing to biased thinking rarely is a desirable state of mind. This is, for instance, the reason why it would be important to overcome stereotypes against drivers belonging to a specific social category.

6. LIMITATIONS

It is important to note the limitations inherent to a web-based experiment on cognitive load. First, even in a laboratory study it is sometimes hard to verify whether subjects in the load cognition were in fact under load and those in the control condition were not [4]. This holds all the more for the approach presented here. Second, web-based experiments are not set within a controlled environment. Although the instructions being provided stressed the need for full concentration, subject distraction may still have occurred. We tried to address this issue by excluding all subjects which indicated they were substantially distracted during the procedure. Of course, being slightly or substantially distracted is rather subjective. In fact, subjects in the load condition are expected to have been distracted to a minimum degree or not at all because otherwise, they were most likely excluded after failing to rehearse the 8-digit number. Last, it is possible that subjects cheated and wrote down the number instead of rehearsing it mentally. However, as an indicator of validity of the present study, drivers' self-perceived superiority was replicated and emerged on a multitude of dimensions.

7. ACKNOWLEDGMENTS

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Towards a Cognitive Load Ready Multimodal Dialogue System for In-Vehicle Human-Machine Interaction

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ABSTRACT
This position paper approaches one of the critical topics in the development of multimodal HMI for the automotive domain: keeping the driver's distraction low. However, the estimation of the cognitive load (CL), of which distraction is one symptom, is difficult and inaccurate. Instead our research indicates that an approach to predict the effect of dialogue and presentation strategies on this is more promising. In this paper we discuss CL in theory and related work, and identify dialogue system components that play a role for monitoring and reducing driver distraction. Subsequently we introduce a dialogue system framework architecture that supports CL prediction and situation-dependent decision making & manipulation of the HMI.

1. INTRODUCTION
Due to the enhancement of on-board electronics in modern cars during recent years, the amount of information the driver receives has been steadily increasing. Traditional car displays and controls like speedometer, light, wiper settings or radio add to the information load that is produced by the actual traffic and environmental context. Nowadays, many modern cars offer much additional information, services and assistance systems for driving, navigation, "infotainment", entertainment and comfort. However, although it is generally accepted that some of this information can be beneficial to increase safety and the driver's comfort, it cannot be denied that the flood of cognitive stimuli harbours the risk of distracting the driver from his primary task, namely to steer the car. Automobile manufacturers face the challenge by developing user interfaces that reduce the effect on CL. This can be achieved by using different interface modalities or adapting the provided dialogue strategies in order to reach a certain goal. Unfortunately there exist only a few patterns and guidelines that support the HMI development process or give an a-priori prediction of the influence of dialogue and information presentation strategies on the driver's workload and the distraction from his primary task. Moreover, the effective load depends on numerous situational parameters that cannot be foreseen, including the driver's mental model and the interplay of stimuli. In this paper, we explore models and strategies for supporting development and evaluation of cognitive load aware multimodal user interfaces.

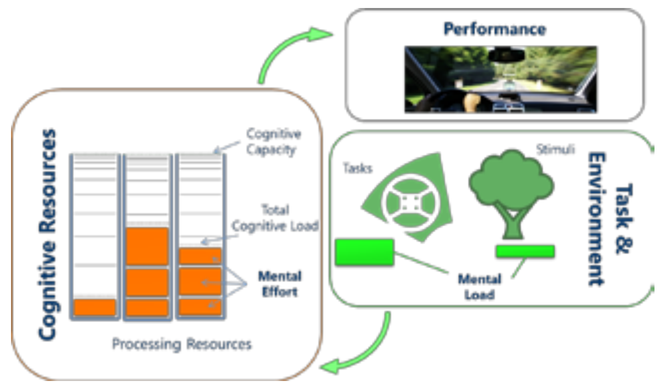

Figure 1: Interplay between mental load, mental effort, performance and CL. Mental load is imposed by stimuli and tasks. The mental effort is the actual allocated amount of CL, that is individual for every user and distributed over different resources. There is a greater interference between two tasks when they share the resources of one category. The overall mental effort for one resource should not exceed the cognitive capacity, since it directly influences the driving performance [19].

2. COGNITIVE LOAD THEORY
In psychology, CL theory addresses the cognitive effort required when learning new tasks. The theory maintains that it is easier to acquire new knowledge and expertise if the kind of learning instruction keeps the CL, and therefore the demand on a user's working memory, low [4][21]. The theory differentiates between three types of CL: *intrinsic load*, *germane load*, and *extraneous load*. The intrinsic load results from an interaction between the amount and type of the material being learned and the expertise of the learner. Extraneous load relates to the manner in which the material being learned is presented. The germane load is needed for processing the learned content and organize it into new schemata or activating existing ones. The three types are additive; together they build the overall load that should not exceed the cognitive capacity limit [18].

Paas and Van Merriënboer [19] describe assessment factors on CL. Figure 1 depicts the simplified interplay between them. The *mental load* is imposed by the task or environmental demands and is constant for a given task in a given environment, independent of a particular user's characteristics. The mental capacity actually allocated is represented by the *mental effort*. It is the outcome of the interaction between the task and the subject's characteristics. Thus, this represents the actual CL on the individual. The quality of the task solution is a third measure, the *performance*. It is influenced by the suspected mental load, the effectively invested mental effort and the individual prior knowledge and experience of the subject.

Current theories for working memory are based on models which consist of multiple independent processors associated with different modes. Baddeley [2] [3] describes the two independent components *visio-spatial sketchpad* and *phonological loop* that are coordinated by a central executive module. The first processes visual input and spatial information, the second stores auditory-verbal information. The *four-dimensional multiple resource model* [22] divides resources into four categories/dimensions, postulating that there is a greater interference between two tasks when they share the resources of one category. The categories are *stages* (perceptual/cognitive vs response), *sensory modalities* (auditory vs visual), *codes* (visual vs spatial) and *channels of visual information* (focal vs ambient) [22].

To sum up, the influence of tasks and cognitive stimuli on the CL is dependent on various factors. These are the task difficulty, the individual experience of the user and the distribution of load among different working memory resources. Finally, also the individual subject can have an active influence on the CL by ignoring information and focusing on a specific task. Furthermore, the working memory theory suggests that a distribution of information presentation on different modalities and the opportunity to solve tasks in a cross-modal way can help to reduce the load on single resources.

3. MMDS COMPONENTS AFFECTING CL

How can the knowledge from theory be exploited for CL awareness in multimodal dialogue systems (MMDS)? We can state that a precise prediction of CL is nearly impossible, since it is dependent on many uncertain factors like the situation, personal experience and even the amount of concentration the driver is willing to invest into a situation. But, theory says that the *mental load* is constant on a given task and independent from the user's characteristics. We want to use this observation as a starting point for CL estimation by finding concepts for the evaluation of dialogue and presentation strategies.
It is not the goal of HMI researchers to explain human cognition in detail. In fact, their research focuses on how presentation and interaction design affect the CL of a user, especially in scenarios in which he controls safety-critical systems like flying an aeroplane, crisis management or steering a vehicle. Some projects treat this question and test strategies for manipulating the CL with changes in interaction design for a multimodal system [15][17]. Related work helped us to identify three components of a multimodal dialogue application that potentially have an influence on the cognitive load:

Multimodal Input & Presentation
The realization of unimodal presentation and the way in which information is presented directly influences the user's attention. [10] analyzed the impact of presentation features like font size and contrast on glance time for a visual display. Presentation complexity on the basis of presentation layout models is predicted in [7]. [6] propose a system design for in-vehicle spoken dialogue complexity management. Other related cognitive research showed that multimodality has a great effect on the CL [16][17].
Hence we assume that the presentation planner is a CL relevant component. Besides the realization of unimodal presentation it coordinates the combination of several modalities (multimodal fusion/fission). Considering the working memory theory postulating that there is a greater interference of tasks if they share the same resource category, presentation planning can keep CL low by selecting modalities with less impact or distributing content on different modalities.

Dialogue Management:
The strategy how to solve tasks in collaboration with the user affects the CL of the user. We demonstrate this by the example of a cinema seat reservation task. In order to successfully reserve a seat, the reservation system needs some relevant information like the movie name, day and time. In a dialogue system the dialogue management is responsible for providing a dialogue strategy that requests this information from the user. The strategies can differ in the amount of information the system collects in a single dialogue turn. One approach is to collect all information at once: A GUI modality would provide a single screen with input elements for all values required ; to use speech dialogue, the system would allow more complex and content-rich utterances. A different approach is to collect the needed information step by step by asking the user in a question-answer-based speech dialogue or by providing multiple GUI windows with lower information density.

Discourse Processing & Context Resolution:
In natural conversations, speakers use referring expressions like anaphora in order to avoid the superfluous effort of rearticulating already established entities. In his *informational load hypothesis*, Almore [1] claims that the noun phrase anaphoric processing optimizes the cost of activating semantic information. Like in the Gricean maxim of quantity [8] a speaker makes a dialogue contribution only as informative as is minimally required. [16] adapts this idea and found out that users communicate more likely multimodally when establishing new content. Following this idea, a component that is responsible for the context resolution of referring expressions and that allows dialogue applications to support multiple forms of referring expressions (e.g. anaphora or deictic expressions) can optimize the CL.

4. MEASURING EFFECTS OF CL

Several measures have been used in psychology and HMI research to estimate the amount of CL. Generally methods can be classified in four categories.

Subjective Measures
A traditional way to assess the subjective workload of a user is *introspection*. The results are acquired by a questionnaire e.g. with the NASA Task Load Index (NASA-TLX) [9]. Because this method is an intrusive procedure and would add an additional task to the CL, it can only be done after the experiment. Beside other scales also in-depth interviews should help to gain more detailed information.

Physiological Measures
One possibility for real-time assessment is to use physiological measures based on the assumption that the subject's cognitive stress is reflected in the human physiology [11]. Physiological indicators that have been used in previous research are heart rate, brain activity, galvanic skin response and eye activity [12, 20] (e.g. blinking or saccadic eye movements).

Performance Measures
Supposing that the performance of task solution is influenced by the CL, conclusions about the latter can be drawn from performance measures. Two performance types can be observed. One is the dialogue task processing performance by considering the amount of time required for solving a task, error rate or type of errors. The other one is the driving performance since the response or reaction time to a stimulus event provides information about the actual CL. An example for this is the Lane Change Test[13], that predicts the level of user distraction by measuring the reaction time of the driver to commands to change lane.

Behavioural Measures
Under high CL users tend to change their interaction behaviour. [5] define *response-based behavioural features* as those that can be extracted from any user activity that is predominantly related to deliberate/voluntary task completion, for example, eye-gaze tracking, mouse pointing and clicking, keyboard usage, use of application, gesture input or any other kind of interactive input used to issue commands to the system. Characteristics of speech, such as pitch, prosody, speech rate and speech energy, can change under high CL. Further features in speech which may indicate cognitive stress are high level of disfluencies, fillers, breaks or mispronunciations.

The different measurement categories involve advantages and disadvantages for the use in a multimodal dialogue system. While subjective measures are not practicable for real-time assessment, physiological sensors are often integrated in cumbersome equipment and it must be guaranteed that the methods are non-intrusive. Furthermore we need concrete models and heuristics in order to map sensor data on concrete CL describing values, to make matters worse a measuring unit for CL does not exist, yet (similar questions arise for behavioural measures). A promising approach is to start with subjective and performance measures that give more concrete conclusions about the driver's distraction and use these findings as evidence for the development and validation of models for the analysis of the two other measures.

5. DESIGN CONSIDERATIONS FOR A CL-AWARE DIALOGUE PLATFORM

Our goal is to create a multimodal dialogue platform that supports state-of-the-art functionalities like multimodal and context fusion, discourse processing and multimodal fission. However, we want to extend this dialogue platform to support research on the estimation of CL and to make it CL-aware. The platform we are building together with an associated development toolkit allows the rapid and flexible creation of new dialogue applications [14]. A great focus is therefore placed on a carefully considered model-based approach and a modular platform architecture with respect to strategies for CL evaluation, estimation and prediction, that allows the easy adaptation or replacement of components. With an adequate development toolkit, the validation of theories and models from cognitive science with live experiments can thus be improved.

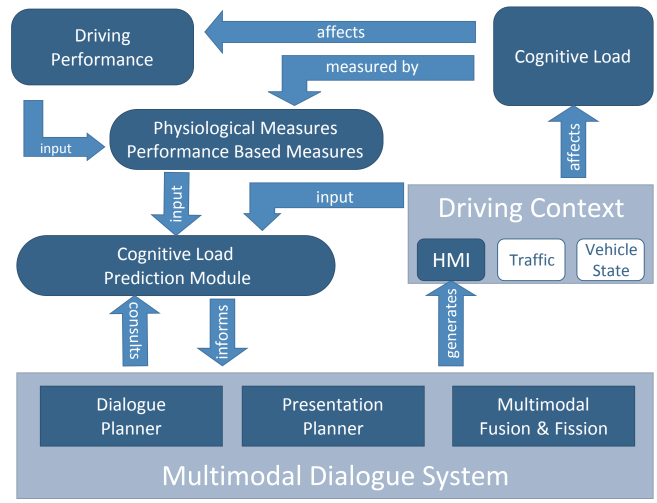

Figure 2: Relevant dialogue system components have a direct influence on the CL and the driving performance. These can be measured and estimated in order to provide situation adapted dialogue and presentation strategies.

Figure 2 shows the concept for our cognitive load aware multimodal dialogue system architecture. The three components mentioned in section 3 (Dialogue Planner, Presentation Planner, Multimodal Fusion/Fission) to a large extent define and generate the human-machine interface (HMI) of the dialogue system that is part of the driving context. This context directly affects the CL of the driver and may have influence on his driving performance. It is possible to integrate arbitrary components for performance and physical measurement. Combined with the driving context they form the source data for a CL prediction module. This module and its algorithms will be adjustable and replaceable for different use cases, theories and measurement methods. Thus, the system will be able to support on the one hand more pragmatic heuristic estimation approaches for use in live applications and on the other hand the evaluation of more complex models from cognitive science.

6. CONCLUSION & OUTLOOK

We designed a multimodal dialogue system platform that allows the rapid development of multimodal applications. We propose to extend and adapt the platform in so far that it is able to support the estimation of the user's current CL. Besides supporting the monitoring of CL the developer should also be able to react to it accordingly by changes in interaction design, e.g. in order to reduce it in subsequent interaction. The following two goals are additionally in focus of our research:

Support for application developers - Results from our studies can be used to find patterns and propose guidelines that help to develop interfaces with a low effect on the CL. Since not every application designer will have adequate experience to apply these in practice, a system that predicts the complexity of an interaction design and supports the application developer in his work will provide a valuable benefit. Thus, during the design process, dialogue platform tools can advise the developer with CL predictions for dialogue and presentation strategies.

Support for situation-adaptive systems - A future goal is to build systems that adapt their communication behaviour with respect to the current context and CL of the driver. For this purpose, our architecture allows the cooperation between the dialogue system and the prediction module in order to plan situation-aware behaviour of the HMI.

7. ACKNOWLEDGMENTS

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Model-based engineering of user interfaces to support cognitive load estimation in automotive applications

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ABSTRACT

In this brief position paper we argue that model-driven engineering practices could be adopted in the design and evaluation of automotive UI. We illustrate how UML state machine models can be used for automatic generation of executable prototypes of the UI and for computing graph-theoretic metrics that could bear upon cognitive load.

Categories and Subject Descriptors

H.1.2 [**Information Systems Applications**]: Models and Principles—*Human factors*; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Prototyping, user-centered design, Graphical user interfaces*; D.2.8 [**Software Engineering**]: Metrics—*complexity measures, performance measures*; D.2.m [**Software Engineering**]: Miscellaneous—*rapid prototyping*; D.2.2 [**Software Engineering**]: State diagrams—*UML state machines, statecharts*

General Terms

Software engineering, model-based user interfaces, model-driven engineering, interaction design, usability

1. INTRODUCTION

Bad usability critically affects embedded systems such as those on board of cars for two reasons. On the one hand, systems are costly to replace (higher costs in recalling, in disseminating, in reinstalling new versions); on the other hand, their context of use is critical, as bad usability in such user interfaces often leads to low safety.

Although advanced UIs can be conceived that reduce drivers' cognitive load, drivers will still have to interact with them. For example, [5] highlight several factors that can lead to drivers' distractions when using a GPS navigator and suggest remedies such as: while driving in familiar areas the level of detail of instructions provided by the navigator should be reduced, whereas it should increase with high traffic density, or bad weather, or when driving in unknown areas. Even with such adaptive navigators that optimize their output, drivers might need to interact with the navigator while driving: to turn off or on its voice, to change view on the map, to get an overview of the suggested route, to see the estimated time or distance to arrival, to locate some intermediate destination on the map, etc. Each of these use cases might require an attention switch that could be fatal, especially if the user interface requires observation and concentration.

To produce designs of user interface that are valid, there is no substitute of iteratively carrying out usability investigations. However, designers use static prototypes (sketches, storyboards, page mockups) or minimally interactive ones (clickable PDFs or slides), which lack most details regarding the dynamics of the user interface. In fact, because prototypes are manually built, not all the data nor all user actions are implemented and can be therefore investigated. As argued by [4], mixed-fidelity prototypes are often needed in order to perform a usability investigation that can reveal major usability problems. Almost always, because of cost, manually built prototypes show poor levels of fidelity in terms of richness of data and of interactivity, reducing the interactions that could be considered during the investigation. And this is despite user actions being an important focal point of designers ([1] offers an ample discussion) and crucial for usability investigations (cfr. "interaction cycle" by [6], goal-action-effect "triangle" [3]).

A different line of attack is based on using metrics. Over the years, metrics have been developed that can be applied to user interfaces with the aim of characterizing some property that bears upon usability. For example, [9] illustrate a number of graph-related metrics that can be used to highlight usability aspects of user interfaces. Using a transition network where states represent screens of the user interface and transitions represent user actions, these authors show that metrics that measure centrality in a graph, such as "betweenness" of states, do bear upon usability defects of devices like hospital infusion pumps, and that findings deriving from such metrics could be used to identify severe problems and hence to prompt for design modifications.

2. MODEL-DRIVEN ENGINEERING

The context of this research is model-driven engineering (MDE) methodologies [7, 8] for developing user interfaces. In general these approaches provide means for using models to direct the course of understanding design, construction, deployment, operation, main-

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tenance and modification of software systems. They combine domain-specific modeling languages, that formalize aspects of the system that are specific to particular domains, with transformation engines and generators that are used to synthesize several types of artifacts, from source code to test cases, in order to achieve the process known as "correct-by-construction", as opposed to the more frequent "construct-by-correction" approach. CAMELEON is a reference framework for model-based approaches to the development of interactive context-sensitive systems. Development and maintenance of user interfaces occur through a layered architecture encompassing different models that separate the concerns [2], and corresponding transformation rules between models.

A basic tenet of *model-based user interfaces* is the ability to specify models that are expressive enough to explicitly represent the properties that are suitable for a given kind of analysis or processing. In our case, we are interested in finding out usability defects associated to the interaction structure and in computing metrics that are linked to cognitive load.

More specifically, with the UML-IDEA project (UML-based Interaction Design Approach) we use UML state machine models (also known as "statecharts") to represent the dynamics of a user interface, UML class diagrams to represent data manipulated by the user interface, and model annotations to associate data and widgets to states, so that one can automatically generate executable mixed-fidelity prototypes to be used in usability investigations. Furthermore, metrics could be computed on models so that properties of the interaction structure can be found.

Although several suggestions on how to use statecharts for modeling user interfaces are already known, UML-IDEA is the first approach that is based on a "model-to-code" transformation of UML state machines, class diagrams and XML annotations, so that the structure of the UI (containers and widgets) is automatically inferred by the system. This allows the designer to specify as detailed information as deemed appropriate, and still be able to generate executable prototypes. In addition, thanks to the orthogonality of the models, the entire mixed-fidelity prototype space can be easily explored by the designer.

At the moment, UML-IDEA encompasses a UI compiler that is capable of processing full UML state machine models, simplified class diagrams and annotations, and of generating executable prototypes in a HTML5/Javascript platform.

3. EXAMPLE

Consider the two models in figures 1 and 2, of cruise control devices on board of two common cars (left anonymous). It is obvious that one model is more complex than the other one: in 2 the user can "store" the desired speed and later on engage the controller so that the stored speed can be reached. In addition, the controller may automatically switch off when the actual speed of the car stays well beyond the desired speed for a certain time period. Models include only transitions that have some effect; though other actions can be performed (such as breaking when the system is in state `Standby`), they are not modeled as they do not affect the system.

One way to understand how that added complexity manifests itself in terms of usability or cognitive load relies on materializing the design into a prototype. Let's imagine that these are two alternative designs. By interacting with prototypes a designer could figure out what sequences of actions are needed to get to a certain state, if in a given state all available actions are needed and make sense, and if all the different states make sense for such an application. With such prototypes, suitably enriched with look and feel aspects, usability experiments could be run to estimate cognitive load and interferences of interactions with driving performance.

Because the chosen models emphasize interaction structure, models themselves provide no help in identifying usability problems that deal, for example, with affordances of controls or with perception of UI components. However, because of the independence of control, data and look and feel aspects, once these look and feel aspects are defined, it is relatively easy to change the UI logic and even the data and reuse them.

Because the state machine model specifies transitions that are associated to either user actions (*e.g.*, the user tapping on a widget) or autonomous actions (*e.g.*, the cruise controller switching off automatically), possible usability problems dealing with timing between relevant events could also be caught when using the prototypes.

As briefly mentioned above, models could be used also to compute graph-theoretic metrics that might be associated to cognitive load. Besides trivial metrics such as number of states, transitions and concurrent regions, other more complex scores can be used to benchmark a model and even to identify weak spots in a design.

To apply such kind of metrics, the UML state machine model has to be appropriately processed so that hierarchical states, hyper-transitions and concurrent regions are flattened[1]. On the resulting directed multi graph (the *interaction graph*), one could assess the following properties among others:

- *Connectivity*: an interaction graph that is not strongly connected has at least one state that cannot be reached from another one. This might mean a partial dead end for the user, whose consequences depend on the meaning of the isolated state. For example, in both models "S" and "A" the final state `Off` has no outgoing edges, but this is by design, and has no negative consequences on interaction.
- *Hinges and bridges*: these are states and transitions that, if removed, cause the interaction graph to become disconnected. Therefore they are states or actions that users need to be aware of, otherwise a set of system behaviors will not be available. For example, the `press` transition leaving state `standby` in model "A" is such a bridge. If the driver is not aware of such an action, then the whole cruise control system is useless.
- *Diameter*: it is an attribute of the entire graph, and is based on the shortest paths between all pairs of states. The larger it is and the more unbalanced the design is, with some pairs of states being far away. It can be used to gauge the potential complexity of a design. For example, in "A" the diameter is 3, while in "S" it is 2.
- *Centrality*: in general terms, a central state in the interaction graph is a state that is important (*e.g.*, because it can be easily reached from many other states). There are many notions of centrality that can be considered, including *eigenvector*, *pageRank*, *closeness* and *betweenness*. Betweenness of a state reflects the number of times that the state is included in a shortest path between two other states; similarly for a transition. High values of betweenness are associated to states or transitions that have to be passed through often. Table 1 shows betweenness scores for our example.

Assuming that user actions require different levels of accuracy and attention, one could attach weights to transitions and observe the analytic consequences of such assumptions. For example, in model "S" certain actions require more attention than others: a `uplong` action means to pull up the lever and keep it there to continuously accelerate the car; when the lever is left the current speed becomes the reference value for the controller. In the met-

[1]This is a preliminary process that in UML-IDEA is needed also for generating prototypes.

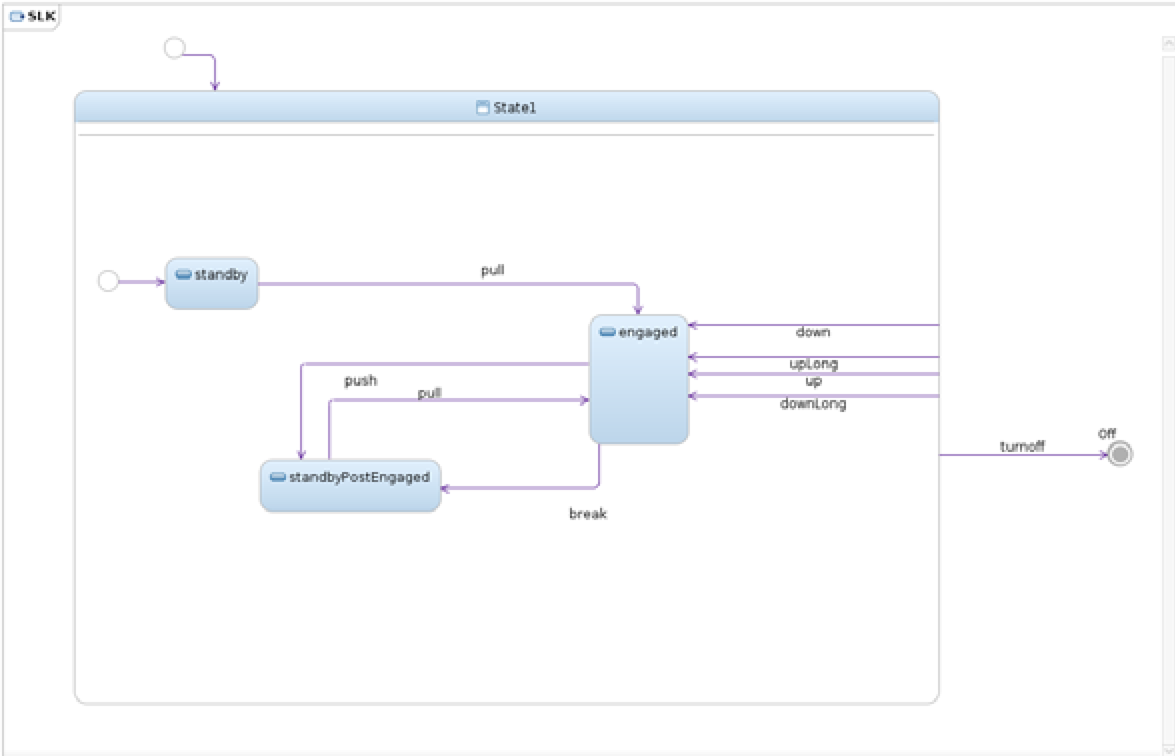

Figure 1: UML state machine model of the cruise control on board of car model "S". Arrows correspond to user actions.

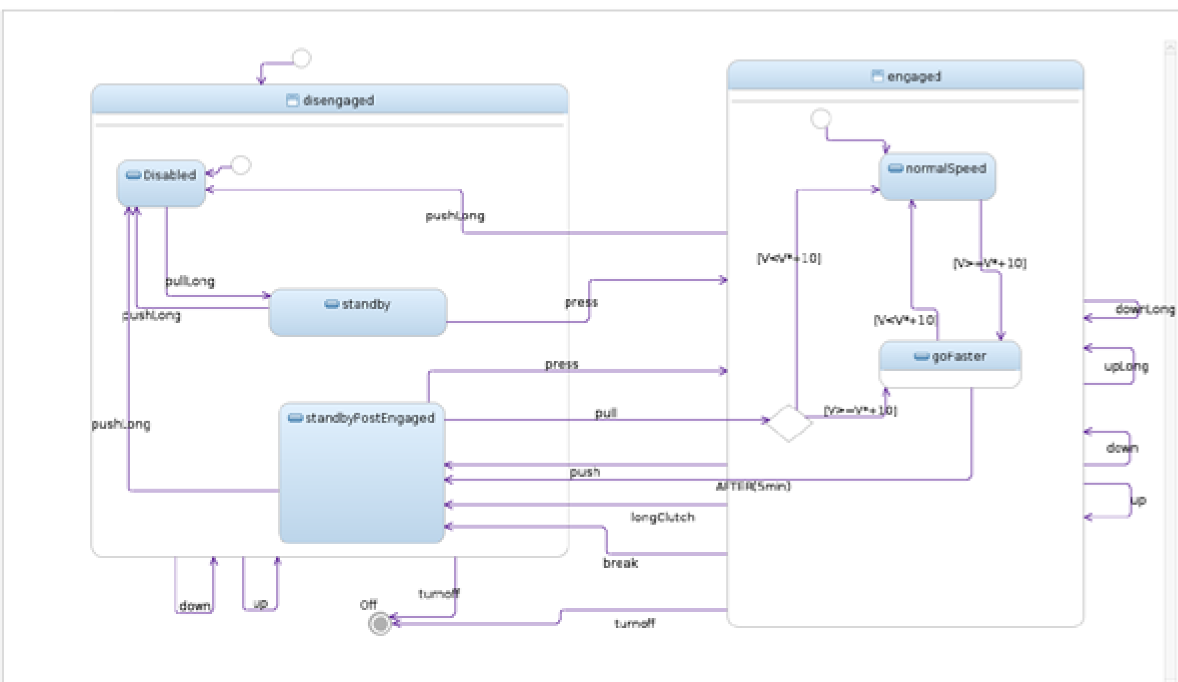

Figure 2: UML state machine model of the cruise control on board of car model "A". Some arrows correspond to user actions, while others are autonomous ones.

	Transition	Source state	Betweenness
	downlong(3)	Standby	0.00
	uplong(3)	StandbyPostEngaged	0.00
	downlong(3)	Engaged	0.00
	uplong(3)	Standby	0.00
	downlong(3)	StandbyPostEngaged	0.00
	uplong(3)	Engaged	0.00
	pull(1)	StandbyPostEngaged	0.33
	up(1)	StandbyPostEngaged	0.33
	down(1)	StandbyPostEngaged	0.33
	pull(1)	Standby	0.67
	up(1)	Standby	0.67
	down(1)	Standby	0.67
	break(1)	Engaged	1.00
	push(1)	Engaged	1.00

	Transition	Source state	Betweenness
	pushLong(3)	GoFaster	0.00
	downLong(3)	Standby	0.00
	upLong(3)	GoFaster	0.00
	downLong(3)	NormalSpeed	0.00
	pushLong(3)	NormalSpeed	0.00
	press(3)	StandbyPostEngaged	0.00
	...	...	0.00
	AFTER(5min)(1)	GoFaster	* 0.83
	break(1)	GoFaster	0.83
	push(1)	GoFaster	0.83
	pull[V<V*-10](1)	StandbyPostEngaged	1.00
	[V<V*-10](1)	GoFaster	* 1.00
	pushLong(1)	Standby	1.00
	pull[V<V*-10](1)	StandbyPostEngaged	1.00
	pull[V>=V*-10](1)	StandbyPostEngaged	1.00
	push(1)	NormalSpeed	2.17
	break(1)	NormalSpeed	2.17
	[V>=V*-10](1)	NormalSpeed	* 3.00
	pushLong(1)	StandbyPostEngaged	4.83
	press(3)	Standby	6.00
	pullLong(1)	Disabled	7.00

Table 1: Centrality of states and some (weighted) transitions in model S (top) and model A (bottom).

rics analysis of the model, we attached a weight of 1 to all actions except for `uplong` and `downlong`, whose weight was set to 3. In other words we are assuming that these two actions are 3 times more difficult.

Because betweenness figures depend on the notion of shortest path in the graph, which in turn is based on the "cost" of followed transitions, the resulting scores depend on such an assumption. For the kind of analysis that we are discussing here, however, choosing any pair of increasing positive values would lead to similar results.

One thing that we can notice in model "S" is that "difficult" actions have a 0 betweenness score, meaning that they are not in the way of the driver who wants to use the controller. And, vice versa, actions that have a relatively high score are simple ones.

Compare these data with the scores obtained from model "A" (Table 1). Notice that several actions with weight 3 have a low betweenness score, which is good. However, the `press` action (to initially engage the controller the driver has to radially press the lever, which requires careful control of the hand movement) has a centrality score of 6, indicating that it is a transition that should be often followed. Transitions marked with "*" are autonomous ones, that do not require a driver action. Notice that the autonomous transition `[V>=V*-10]` (which occurs when the actual speed exceeds the set one by 10 or more km/h) has a relatively high centrality, meaning that it could occur often. Therefore appropriate indicators should be used in the user interface to notify the driver of such a change (such as turning on or off a particular symbol in the dashboard, or changing its color.

4. CONCLUSIONS

We attempted to show that model-driven engineering practices could be beneficial for automotive user interfaces. Such an approach could be adopted to quickly generate running prototypes so that usability of the UI can be assessed. A second usage is in applying graph-theoretic metrics that can be used to benchmark a design, to compare 2 or more designs, to estimate cognitive load associated to interaction, and even to spot possible weak points.

Currently we are working on in-vehicle devices that require user interaction, such as infotainment systems and GPS navigators. We are collecting evidence that this rapid prototyping approach coupled with the ability of using metrics is effective in spotting weak areas of a design and supports informed rapid changes so that a designer can easily explore a large design space. We are also exploring the space of available metrics and validating promising ones.

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AutoNUI: 3rd Workshop on Automotive Natural User Interfaces

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ABSTRACT
Natural user interfaces—generally based on gesture and speech interaction—are an increasingly hot topic in research and are already being applied in a multitude of commercial products. Most use cases currently involve consumer electronics devices like smart phones, tablets, TV sets, game consoles, or large-screen tabletop computers.

Motivated by the latest results in those areas, our vision is to apply natural user interfaces, for example gesture and conversational speech interaction, to the automotive domain as well. This integration might on one hand reduce driver distraction in certain cases and on the other hand might allow the design of new user experiences for infotainment and entertainment systems.

The goal of this workshop is to continue the discussion and exploration of the design space of natural multi-modal automotive user interfaces and to continue the fruitful discussions held at the first two workshops on Automotive Natural User Interfaces at AutomotiveUI 2011 and 2012 [8], [9]. We would like to analyze where and how new interaction techniques can be integrated into the car – for manual and (semi-) autonomous driving situations.

Categories and Subject Descriptors
H.5.2 [**Information interfaces and presentation (e.g., HCI)**]: User Interfaces – Input devices and strategies (e.g. mouse, touchscreen), Interaction styles (e.g., commands, menus, forms, direct manipulation), Natural language, Voice I/O.

Keywords
Automotive user interfaces; gesture interaction; multimodal interaction, natural user interfaces, speech interaction.

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1. INTRODUCTION
Human-computer interaction (HCI) depends, in most use cases, on the context in which the interaction between user and computer takes place. This is especially true for the automotive domain with its multitude of environment-specific requirements. The primary task of driving a car can itself often be very challenging for the driver — despite advances in assistive driving — especially as overall traffic density is growing. At the same time the car's cockpit is getting more complex due to new, feature-rich assistance and infotainment systems on both built-in and mobile devices. In order to complete secondary and tertiary tasks [2] with these systems, many drivers execute several tasks simultaneously besides the driving task. Efficient and easy-to-use HCI is therefore of particular interest in the automotive domain, with the background goals of most research being the reduction of driver distraction and the support of safe driving.

According to the U.S. Department of Transportation, the average time drivers spend per day in their cars while commuting, shopping, or traveling is 43 minutes/day in Europe and 86 minutes/day in the United States. As most drivers spend this time alone, they demand ever-wider entertainment options and an almost living room-like environment for their vehicles. This underlines the need to enhance the emotional attachment between driver and car. Interaction design with an eye towards usability can help to foster this attachment. Furthermore, societal and IT trends are resulting in an always-connected environment in which drivers and passengers demand constant access to information and in which vehicles have to be aware of their surroundings. Adding to this challenge are upcoming systems for (semi-) autonomous driving as well as the increased prevalence of car-sharing and a higher need for information when using electric cars. New interaction techniques are clearly needed to enable a new generation of interactive systems for information access and the accomplishment of tertiary tasks while driving.

Buttons and similar physical controls are still predominant in the automotive design space [4], however the increasing number of available functions has lead to a situation where dashboard space precludes a one-to-one mapping from physical key to function. In order to circumvent this problem, current systems tend to provide hierarchical menu structures to access certain functions. The drawback of this approach is that immediate access to these hierarchically nested functions is no longer possible. This might lead to longer task completion times and—depending on the visualization—might increase visual distraction.

The introduction of new electronic consumer devices like smart phones, tablet computers, and game consoles has brought with it new ways of interacting with computers and embedded devices. Thus, a growing number of people today is used to interacting with touch-sensitive devices (touchscreens and touchpads) and many have some first-hand experience with speech technologies and gestural interaction. Within HCI research, "natural user interfaces" (NUIs) [11] have become a fruitful research topic encompassing multi-touch and full body gestures, conversational dialogs and affective systems, among many others. The introduction of computer vision-based tracking technology like the Kinect for Xbox 360[1], Leap Motion[2] and natural speech systems like Apple's Siri[3] has extended the interaction space for consumer devices. Inspired by these developments, the question arises whether these interaction techniques might also be suitable for automotive user interfaces. Although some early research has been carried out in the automotive context (e.g., [1], [5], [7], [10]), only some basic touch- and voice-activated interfaces have found their way into deployed in-vehicle systems so far. Gestural and multimodal interfaces are not yet broadly deployed. As they might facilitate the execution of secondary or tertiary tasks without increasing driver distraction, the integration of such interfaces is of particular interest (e.g., [6]). Moreover, further development of display technologies like glasses-free 3D, high resolution, shaped, or transparent displays offer new ways for visualizing interactive as well as informative content. So far, output technologies are less investigated in terms of natural user interfaces and especially inside the car.

Additionally, natural user interfaces have the potential to enhance the user experience. Designing experiences with these user interfaces can address and fulfill psychological needs of the user while interacting with the car (e.g., [3]). The resulting emotional attachment to the car can ease the acceptance of a system and avoid disuse. Considering the daily drive times mentioned above, the user experience offered by automotive user interfaces´is likely to gain prominence in the car-buying decision. This will become even more important with the rise of assistive systems and autonomous driving modes when the driver might have more time to concentrate on secondary and tertiary tasks. Depending on the situation, these interfaces might still need to offer easy means of notifying the driver to re-gain control of the car.

Besides supporting interaction for the driver, suitable infotainment and entertainment functionalities are also of special interest for co-drivers and passengers on the backseat. Compared to living room setups, the interaction space for passengers is limited by the dimensions of the car and through safety regulations (e.g., wearing seat belts). In combination with the increased robustness requirements of a moving environment, multimodal, natural interaction might also support this sub-domain of automotive user interfaces.

[1] http://www.xbox.com/kinect

[2] http://www.leapmotion.com

[3] http://www.apple.com/iphone/features/siri.html

Besides integrating these technologies into the car in general, we must also be concerned with how potential new interaction techniques are designed and evaluated. How can individual NUI technologies be used, and how might they be combined in new and interesting ways to foster the overall user experience?

2. OBJECTIVES

This workshop addresses the following issues:

- Generating an overview of which (natural) user interfaces are already used in the car and how they might be used in the future.
- Concepts for future multimodal interactions in the car.
- Discussion of new display modalities in the car (e.g. 3D displays, shaped displays).
- Automotive user interface frameworks and toolkits.
- Looking into special sub-domains: the driver, the co-driver, the backseat area, or connection to the outside.
- Understanding the definition of "natural" for different users. What are the differences across generations, cultures, and driving habits (e.g., occasional drivers vs. professional drivers)?
- Understanding how NUIs can be used in the automotive domain: do they replace or rather augment other interfaces?
- Discussion of potential issues of bringing NUIs into the car.
- Researching the relevance of traditional UX factors to the automotive NUI context.
- Researching how UX factors might motivate the integration of new NUIs into the car.
- New concepts for in-car user interfaces enhancing UX and experience design in the car.
- Multimedia interfaces, in-car entertainment, in-car gaming.
- Future trends: the ubiquitous car in a mobile society.
- Automotive user interfaces supporting the special needs and flexibility of (semi-) autonomous driving modes.

3. BEFORE THE CONFERENCE

The workshop organizers will commit to publicize their workshop. The call for participation for this workshop will be distributed via HCI and Automotive UI related mailing list like, e.g., ACM SIGCHI, British HCI News, and Local SIGs lists. Additionally, we intend to distribute the call for participation as a one-page leaflet at HCI related conferences. We will further use our own/personal distribution lists. The website of the workshop series[4] will be updated in order to provide information about the upcoming workshop, the submission modality and links to related material, so candidates can get familiar with the scope of the subject and the goals of the workshop. Accepted position papers and other pre-workshop materials will be made available to participants. This way, presentations during the workshop can be kept short and the reflection on the subject is stimulated before the workshop. In the sense of the workshop we will set up a weblog on the workshop website to facilitate a pre-workshop discussion.

[4] http://blog.hcilab.org/autonui

4. DETAILED PLAN FOR CONDUCTING THE WORKSHOP

This workshop is planned as a one-day workshop with breakout sessions, alternated with a moderated group discussion.

The workshop will start with an introduction to the workshop topic (9:00-9:15), followed by very short introductory presentations (e.g., in a pecha kucha style) to get familiar with the participants and the topics they are working on. The introductory presentations will be kept short and focused, so there is ample time for discussion (9:15-10.30). After the break (10:30-11:00) the organizers present the common themes of the submitted papers, grouping them into different sessions (3-5 topics). The different groups will then discuss their topics during a first breakout session, creating a list of conclusions (11:00-12.15). The organizers will actively interact with the audience to stimulate discussion around the workshop topic.

After the lunch break (12:15-13:15) a short alignment of pre-lunch discussions will happen in the whole group. This continues into a second round of break-out sessions to further discuss grouped topics (13:15-14:30). After the coffee break (14:30-14:45) the results of the breakout sessions will be discussed in the whole group. The conclusions of the workshop will be worked out and follow up activities will be specified (14.45-16:00).

5. PARTICIPATION

Workshop candidates are requested to submit a position paper (no longer than 4 pages in the CHI extended abstracts format) about their research that links to the workshop theme. Participants will be selected on the basis of the relevance of their work and interests and familiarity with the topic.

6. EXPECTED PARTICIPANTS AND SELECTION PROCESS

The workshop aims to bring together researchers, students, and practitioners, who are interested specifically in the automotive context. In particular, we hope for participants with different backgrounds and perspectives, e.g., automotive user interface (UI) designers, experience designers and engineers from a scientific as well as from an industrial perspective are welcome to submit position papers and join the workshop. The number of participants should be limited to 20. Participants will be selected based on their submission through a review process. The organizers as well as selected researchers working in this area will form the program committee and will conduct the review process as usual for this kind of venue.

7. OUTCOMES

We have identified the potential for a fruitful continuation of our workshop series on Automotive Natural User Interfaces [8], [9]. We want to give researchers and practitioners the possibility to discuss the ways of integrating NUIs into the car and measuring the “naturalness” of their designs. We think that it is furthermore necessary to identify challenges related to understanding and addressing users’ psychological and affective needs with respect to automotive user experiences. We expect that the coverage of these topics will further participants’ understanding of the role of NUIs in the car, and that workshop outcomes advancing automotive NUIs will more broadly advance the entire discipline of automotive user experience.

To capture the outcomes of the workshop, different methods will be taken. On the one hand, we intend to build up a website that discusses the different ideas on natural user interfaces. The idea is to ask all workshop participants to take part in building up content for this website and do so even beyond the boundaries of our workshop. As the topic of natural user interface has already advanced quite a bit over the last workshops, a second idea is to also discuss the creation of a book on natural user interfaces. In this case, a call for participation could be set up after the workshop to write and submit chapters for this book. Workshop participants would be encouraged to extend their workshop contribution into separate book chapters. In order to ensure a certain scientific contribution of this book, a suitable review process would be set up.

8. Organizers’ Backgrounds

Bastian Pfleging holds a Master’s (Diploma) degree in Computer Science from TU Dortmund, Germany. He is a research assistant at the Human-Computer Interaction Group of the Institute for Visualization and Interactive Systems (VIS) at the University of Stuttgart, Germany. His general research interests are multi-modal and natural user interfaces. In particular, he is interested in human-computer interaction in the automotive context. From 2010 to 2011 he was visiting the BMW Technology Office in Palo Alto, CA, USA. Bastian was involved in organizing the first two workshops on Automotive Natural User Interfaces at AutomotiveUI ’11 and ‘12 and was Publication Co-Chair of AutomotiveUI ‘12.

Ignacio Alvarez received a PhD from the University of the Basque Country and was a Research Assistant at the Human-Centered Computing Lab of the Clemson University. His research areas encompass ubiquitous computing, automotive user interface design, spoken-dialog systems and affective computing. Since 2009 he worked as a research associate at the BMW IT Research Center in South Carolina in the fields of mobility services and user experience. In February 2012 he joined BMW AG as IT Systems Architect focusing in development of vehicular speech technologies.

Jennifer Healey is a scientist at Intel Corporation Research Labs, she researches devices and systems that would allow for innovations that imagines a future where computers and smartphones are capable of being sensitive to human emotions and where cars are able to talk to each other, and thus keep their drivers away from accidents. She holds a PhD from MIT in electrical engineering and computer science. While there, she pioneered “Affective Computing” with Rosalind Picard and developed the first wearable computer with physiological sensors and a video camera that allows the wearer to track their daily activities and how they feel while doing them. From there, she moved to IBM where she worked on the next generation of multi-modal interactive smartphones and helped architect the "Interaction Mark-Up language" that allows users to switch from voice to speech input seamlessly.

Nora Broy holds a Master’s degree in Computer Science from TU Munich, Germany. She is a PhD candidate at the Human-Computer Interaction Group of the Institute for Visualization and Interactive Systems (VIS) at the University of Stuttgart, Germany. Her general research interests are new display modalities in the car. In particular, she aims at integrating 3D content and interaction into the car. In 2011 she was visiting the BMW Technology Office in Palo Alto, CA, USA and is now affiliated with BMW Research & Technology in Munich, Germany.

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Could You Please…? Investigating Cooperation In The Car

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ABSTRACT

In this paper, we present the results of a study on the perception of driver and passenger when cooperating in the car. An increased feeling of control when handing over responsibility for secondary tasks to the passengers might form a basis for the acceptance of future natural cooperative in-car information systems. Many studies have revealed the potential of involving accompanying passengers, but so far, their ability to support the driver has not been applied practically. We have developed a system to support driver-passenger cooperation and investigated the effect on perceived control and involvement. An application to search for points of interest (POI) was implemented and tested in a user study. Besides the POI task, the driver had to perform a distraction task to simulate a dual task load. We found that, depending on the person who is executing the task (driver or passenger), the respective person feels more involved in the situation. However, the level of control over the situation is increased significantly for both persons when the passenger is supporting the driver by performing the task. Overall, we provide a new design space for interaction areas in the car and highlight the potential passengers offer to reduce driver's load and thus increase driving safety.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – *computer-supported cooperative work.*

General Terms

Design, Human Factors.

Keywords

Cooperation, control, involvement, driver-passenger interaction, in-vehicle information systems, touch interaction, large display spaces.

1. INTRODUCTION

Today's in-vehicle information systems (IVIS) are mainly designed to be controlled by the driver. However, the cognitive load required for interaction with the IVIS distracts the driver from the primary task, no matter what input modality is used [3]. On the other hand, passengers in a shared ride are free to do whatever they like as long as this does not have an impact on the driver. They can use smartphones to retrieve information, use both hands for interaction and do not need to observe the traffic situation.

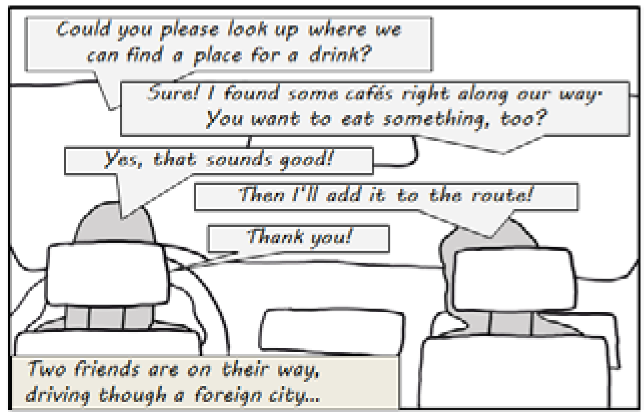

Figure 1. When driving with passengers, their potential to support the driver often remains unused. We propose to give the passenger a dedicated interaction space, and find that the driver can benefit and gain more control over the situation.

We suggest letting the passenger support the driver by carrying out a main part of the interaction with the IVIS (Fig. 1). This can potentially disburden the driver but might also conflict with existing habits and make the driver feel cut out. We conducted a qualitative study to test the acceptance of transferring responsibility to the passenger. The task was to find POIs in a map-based application while the driver was performing a distraction task. We found that, depending on who is performing the task, the active person feels more involved in the situation. However, when the passenger is interacting, the feeling of control can be increased for both. Moreover, we found that for the design of cooperative systems, it is important to avoid additional distraction of the driver by the actions of the passenger. Our findings suggest that it is worth the effort to design cooperative systems to enhance the driving experience for all parties.

2. RELATED WORK

There has been a vast amount of research that investigated the driver-passenger situation in the car. Regan and Mitsopoulos [10] highlight in their report on behavioral interaction between drivers and passengers that there is an influence on vehicle safety when a passenger is present. Especially for young drivers and male passengers, this effect can be negative when drivers want to prove themselves; however, the authors also highlight the potential of the "extra set of eyes" that drivers might benefit from. Forlizzi et al. [1] investigated the social aspect of in-car interaction with a focus on navigation. They recommend to adapt human-machine-interaction to inter-human communi-cation (i.e. customize information context-dependent and to prior experiences). This is still difficult, despite the growing amount of available information and thus points towards "making use" of the humans themselves in shared rides. Gridling et al. [2] conducted an obser-vational study and found that passengers already help the driver, e.g., to gather information, and that trust is a main factor that influences the collaboration between driver and passenger. They recommend providing different information depending on the person who is interacting. Similarly, Laurier et al. [6] analyzed several video-recorded trips with a variety of backgrounds, social and technological. They state that *"passengering"* is often more than just being driven from A to B. They often get involved in the demands of driving the vehicle, and thus can be seen as some kind of "crew-member". Inbar and Tractinsky [5] pointed out that the interaction between driver and passengers can potentially improve travel safety and experience, and suggest to support the sharing of information. Thereby they raise the question of "How [can] drivers transfer some of their tasks to passengers, while remaining in control?" Perterer et al. [9] suggest to better integrate the passengers, especially the front-seat passenger, by providing them with a dedicated interaction space. They report a study where a split view on navigation data, realized with both a navigation device and a smart phone, helped to cope with a critical situation by allowing the passenger to search for further information while the driver was still provided with an overview over the situation. Further developed as one system, it can help to integrate additional content of a passenger-dedicated interaction space into the driver's view as needed. Moreover, it can help to monitor car-related information without disturbing the driver's interaction space.

3. DESIGN SPACE

Large touch screens have been used in concept cars for a while, and with the recent release of Tesla's Model S[1] there is now a car in the market that makes use of a large interactive surface integrated in the cockpit. In a next step, this display area could be extended towards the passenger's side. Concept cars like the Toyota Fun Vii[2] even integrate the rear seat passengers in a shared display space. Scott [11] observed the social behavior when interacting together on shared workspaces and found that dedicated spaces for individual and cooperative work are created to coordinate collaboration. People tended to perform a task in a personal space right in front of them, while shared spaces were used when interacting together.

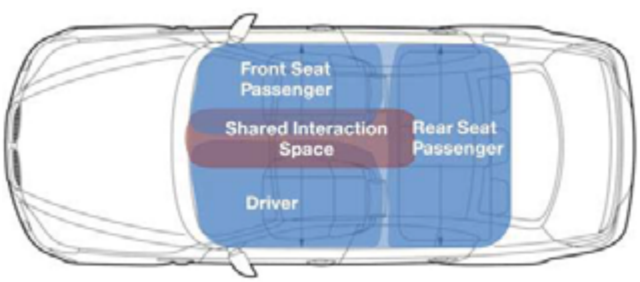

Figure 2. Design space areas in the car (driver, front seat passenger and rear seat passenger) - in combination with a shared interaction space (adapted from [7]).

We wanted to transfer this principle to a problem solving task in the car, in which driver and front seat passenger have their own interaction space, but also a shared space to collaborate. On the driver's side, the dedicated space can be the instrument cluster or a head-up display (HUD) that can be used for car-related information. Those are not suitable for direct interaction, so driver input has to take place on the steering wheel or in the center console region. The passenger has no restrictions regarding the in- and output modalities. Both hands can be used, and full attention can be turned towards the interaction. A shared space needs to be placed in reach for all parties; therefore a suitable space is the center console. Traditionally, radio and climate functions are located here to ensure direct access of both driver and passenger. We took the approach of Meschtscherjakov et al. [8] and adapted their design to extend for a further design space in the car integrating shared interaction (Figure 2).

4. INTERACTION DESIGN

We conducted a workshop to assess potentially meaningful situations and use cases for driver-passenger cooperation. We decided for tasks to support way finding on a shared trip with friends. There are many other tasks a passenger can perform, like reading and writing emails, online search etc. However, to provide additional benefit and not introduce more distraction than necessary, the following three tasks were chosen. All of them are already possible with the functionality current IVIS or smart phone apps offer, but shall now be integrated in one system.

BankFinder and *BarFinder* are designed to be used by either driver or passenger to display the respective points of interest on a map. Further details like opening times or ratings are displayed in a pop-up. *TourPlanner* is a joint sightseeing application that can be used to set up a route along various points of interest. The passenger is able to get a more detailed view, whilst the shared screen gives an overview over chosen POIs, and the possibility for all parties to rearrange them (Figure 3).

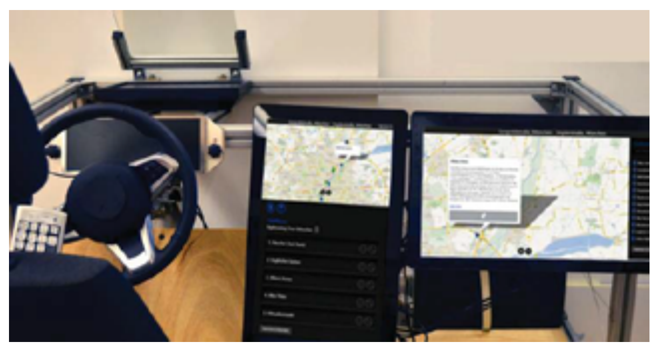

Figure 3. Hardware setup of the user study, running the *TourPlanner* app. Left: The shared view in which both driver and passenger can adjust the tour. Right: Passenger view that includes more details and more possible interactions.

5. USER STUDY

To investigate the influence of a supporting system on the perception of control and involvement, we conducted a user study integrating driver and front seat passenger.

5.1 Participants

Eight groups of two people took part in the study (4 women, 12 men, mean age 28). All of the pairs knew each other beforehand. Friends and colleagues are reported to be the largest group of passengers after spouses and children, whereas foreigners only play a minor role [10]. 56% prefer to take the role of the driver, while the others prefer the passenger's role (13%) or are indifferent. The roles for the study were assigned randomly. All participants are driving in a car at least once a week in both roles

[1] http://www.teslamotors.com/models
[2] http://www.toyota.com/letsgoplaces/fun-vii-concept-car/

and use touch interaction on smartphones or tablets in their daily life. For details on the apparatus see Figure 3.

5.2 Apparatus

The hardware setup (Figure 3) consists of a steering wheel, a car seat for the driver and an additional chair of equal height for the passenger. Two 22'' multi touch capable displays (Iiyama ProLite T2233MSC) were attached to form the central, shared information display and a front seat passenger information display. A 17'' display (Asus VB175T) and a mirroring glass plate were used to imitate a HUD. The instrument cluster display was not used. Additionally, a numpad (Keyboard KL-368) was attached to the left side of the steering wheel, so the driver's primary task could be performed with her left hand.

5.3 Experimental Design

The first part of the study used a within-subject design with the two levels *driver* and *passenger* for the **executer** performing the task. The used **app** (*BarFinder* or *BankFinder*) was counter-balanced. In the second part, driver and passenger were using *TourPlanner* together to reveal insights into their behavior when performing a more complex task. A simple distraction task was deployed to keep the driver's attention on the simulated HUD, i.e. the area where attention on the road would take place. Similar to a lane change task, where drivers are asked to change lanes depending on signs along the road [7], drivers had to respond to highlighted arrow signs as fast as possible on a numpad attached to the steering wheel (Fig. 4). We measured the driver's distraction with both reaction times and interview questions. Moreover, we used questionnaires on perceived usability (SUS) and experience (AttrakDiff). In between the tasks and afterwards, we conducted semi-structured interviews to assess subjective feedback on involvement and feeling of control.

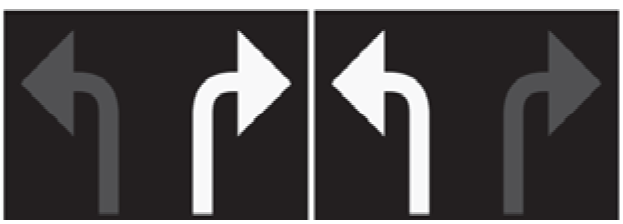

Figure 4. Arrow signs the driver had to respond to as a means of distraction to simulate a primary driving task.

5.4 Study Procedure

Participants took part in the study in groups of two. They were introduced in the scenario, driving together in a foreign city, and in the main functionalities of the integrated system on the two screens. The driver was introduced in the distraction task and performed a test run. The study began by starting the distraction task, and the experimenter gave the driver the instructions to find either a bar or bank with specific properties along the way, to be forwarded to the passenger. After both parties had executed the tasks, they were instructed to put together a tour for the next day, containing five sights. During the study, the experimenter was present to answer questions, observe unusual behavior and record comments.

5.5 Results

All results are reported at a significance level of .01. Subjective results are based on 7-point Likert scales.

After each task was performed by either driver or passenger, both were asked how they **perceived** their **control** over the situation. This was specified to include both primary and secondary task. Results in Figure 5 show that the driver feels disburdened when the secondary task is fulfilled by the passenger. We observed that performing both primary and secondary tasks led to confusion and errors of the driver, while no errors were apparent when the passenger was interacting. On the other hand, the passenger feels much more integrated and thus in control. Moreover, the imbalance between the perceptions is neutralized. Therefore, we conclude that letting the passenger execute tasks can significantly enhance the feeling of control for both parties, while having the driver taking all the responsibility does not only make him feel less in control, but also creates a situation of disparity, as ratings of driver and passenger were only significantly different when the driver was executing.

Figure 5. Perceived control (*"Did you feel you could control the experienced situation?"*)

When performing the *TourPlanner* task together, both had a high feeling of control, indicating that not only the direct interaction with the system is important. Browsing details of POIs was mainly performed by the passenger, but when analyzing the comments, it seems that the driver feels to have a direct influence because of the shared discussions on the results and the possibility to step in the final selection and arrangement in the shared interaction space.

A further question after each condition was, how **involved** in the current action driver and passenger felt (Fig. 6). Using *BarFinder* and *BankFinder*, the respective executer experienced a higher involvement when performing the task. This difference was not significant. Regarding the *TourPlanner*, both parties rated the involvement equally high. Even though the passenger took the main part of the interaction, common discussions on the shared goals raised the perceived participation for the driver.

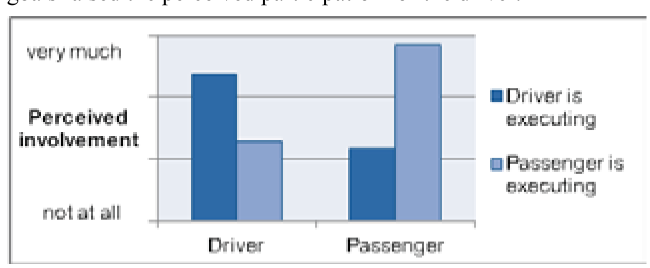

Figure 6. Perceived involvement (*"How involved did you feel in the experienced situation?"*).

Fehler! Verweisquelle konnte nicht gefunden werden. shows the reactions times as a measure of **distraction** while performing the primary task for the different tasks during the study. The driver reacted significantly slower to the arrow signs when he was performing the task than when the passenger was interacting. In the shared task (*TourPlanner*), when both parties were interacting, only a slight increase was observed. The driver was also asked to rate the perceived distraction of the primary task. The results support the measured reaction times.

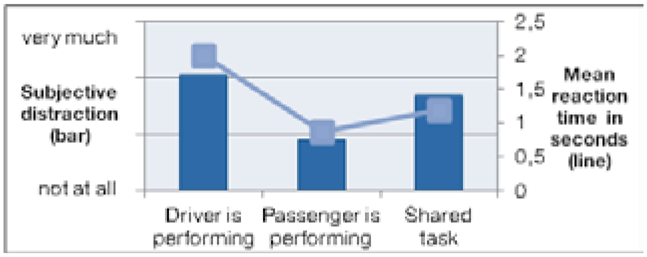

Figure 7. Mean reactions times (in sec) and perceived distraction in the primary task (*"As how exhausting did you perceive the distraction task"*) (drivers only).

The SUS showed high ratings for both driver and passenger. Using the AttrakDiff, we assessed the **hedonic and pragmatic quality** of the overall system (Figure 8). Pragmatic quality was rated high so we con-clude the functional goals that emerge in a cooperative task are well supported. By providing the passenger with more information than the driver could handle, overall functionality can be increased, while an over-view over the current status is constantly accessible for the driver. The hedonic rating shows a high value, yet there is room for improvement. Due to the study setup, participants mainly fulfilled their behavioral goals [4]; further experience with the system would be needed to investigate the impact on hedonic quality.

We **observed** that people, especially the drivers, wanted to know what the passenger was doing. Most of the people started commenting on their current actions to keep the other one informed. Otherwise, the drivers sometimes neglected their primary task to sneak a peek on the passenger's display. We conclude that it is important that the driver is not distracted by what the passenger is doing, but should always be informed about the current status. Tang [12] has highlighted that in a collaborative environment, everybody should be able to observe the current status. This can for example be achieved by constantly displaying high-level results of the passenger's interaction to the driver.

6. DISCUSSION AND LIMITATIONS

We observed a positive effect of integrating the front seat passenger into the execution of tasks related to the current driving context. Perceived control over the situation was raised for both parties when the driver concentrated on the primary task and the passenger performed additional secondary tasks. Carrying out the study in a lab setting made it possible to control the primary task's difficulty and thus to compare the results of the different conditions. However, a real driving task, where the distraction level changes constantly, might influence the results. A further interesting aspect would be to investigate the impact of different levels of complexity of the secondary task. A more complex secondary task could increase the willingness of the driver to hand it over and foster discussions. Further experience and easiness of exchanging information might also increase the acceptance of cooperation.

7. CONCLUSION

In this paper, we investigated the design space of shared interactions in cars by taking additional persons in the car into account. The results show that handing over tasks to a passenger does not degrade the driver's feeling of control for the overall situation but can actually increase it when demanding primary tasks claim the attention. On the other hand, the disparity of perceived control when the driver performs all upcoming tasks can be resolved when the passenger is actively involved. In summary, we encourage researchers to design IVIS to make use of all available cognitive capacity in a car. This can decrease driver distraction without decreasing the feeling of control.

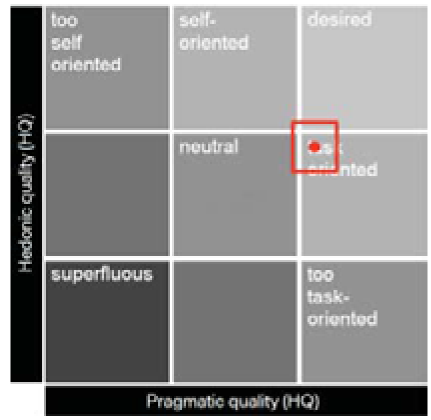

Figure 8. Perceived user experience.

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Toward Natural User Interfaces in the Car: Combining Speech, Sound, Vision, and Touch

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ABSTRACT
The solution to reducing driver distraction from complexities of visual-manual interfaces lies in combining a variety of driver interfaces to fit specific tasks. Text entry while driving is the most critical role that speech plays. But holistically, complex infotainment systems require simple user interfaces that are multimodal.

In this paper we describe a multimodal human machine interface (HMI) model that pertains to driver actions such as task selection, list management, entering text strings, understanding warnings, interrupting or pausing a task, resuming a task, and completing a task—which are required to perform a growing assortment of in-vehicle, non-driving tasks. This model is derived from recent research results of which we provide example tasks and their associated user interfaces to clearly show the dependencies and efficiencies of each modality.

Categories and Subject Descriptors
H.5.2 User Interfaces, H.1.2 User/Machine Systems

General Terms
Management, Measurement, Documentation, Performance, Design, Experimentation, Human Factors, Standardization, Theory.

Keywords
Natural Language Interfaces; Speech Interface; Multimodal; Vehicle UI Recommendations; Driver Distraction Research

1. INTRODUCTION
New federal guidelines developed to minimize visual and manual dashboard distractions to drivers are beginning to validate the need for interactive voice commands for performing tasks secondary to driving.

More immediate reductions in distractions are likely to result, however, by incorporating voice (or speech) technology with a mix of audio, visual (including head-up displays), manual, gesture, and haptic (vibrations) interfaces consistent with Figure 6 described later in this paper.

Numerous studies [1][8][6][2][3] have been completed with more underway attempting to analyze the variables of driver distraction mixed with performing secondary driving tasks while maintaining safe driving performance. Some conclusions drawn are critical to anything other than driving, such as the recent Automotive Association of America (AAA) study, "which conducted tests that found dangerous distractions still exist when drivers use speech recognition behind the wheel to receive, send, or reply to email, text messages, or social media posts" [5]. Others conclude that speech interfaces reduce distraction over manual entry of the same tasks [6]. Despite the highly questionable quality of most speech interfaces, the public is still clamoring for these systems in their cars, as the JD Powers emerging technology survey results attested [5].

2. THE ISSUE
While a growing body of evidence from research is pointing to the importance of interactive speech systems in vehicles to keep drivers eyes on the road and hands on the wheel, the research also reveals the need to avoid voice menus and minimize the amount of speech interaction for drivers. Both actions tend to extend the duration of non-driving tasks, thereby increasing the risk of driver distraction.

A common problem encountered with in-vehicle speech-only interfaces is that a driver often doesn't know what to say in response to the talk button's "please say a command" voice prompt, thereby confusing the speech system as it listens for a response. Also unexpected sounds within the vehicle during this listening mode can confound the system. Both issues can trigger the system to produce seemingly inaccurate results, generating driver frustration, which in turn may result in driver distraction or early abandonment of using the system.

3. INTERACTION CONCEPT
Finding the right combination of interdependent interfaces is where the cutting edge of in-vehicle HMI research is leading.

Reducing distraction will require matching the right blend of natural interfaces that can successfully and quickly perform specific, independent actions—such as task selection, list management, entering text strings, understanding warnings, interrupting or pausing a task, resuming a task, and completing a task—which are required to perform a growing assortment of in-vehicle, non-driving tasks.

One promising approach to overcoming shortcomings in speech-only interfaces is by integrating the vehicle's talk button (commonly found on the steering wheel) with the vehicle's touch screen (or other user interface), providing the driver with a simple, more instructive Tap-or-Say prompt.

Verbally coaching the driver what to say—a speech system's common response when an error occurs—extends the duration time to complete the task, thereby, increasing the potential for driver frustration and distraction. With the Tap-or-Say approach (refer to **Figure 1**), the user instinctively glances and taps from a list of items displayed on a touch screen without the need to contemplate a spoken response. No extra prompting and no extra dialog steps are required, dramatically reducing the task completion time and the risk of distraction [7].

Figure 1. Tap or Say Using Natural Language

Interactive speech will remain a critical interface in the moving vehicle—primarily as a substitute for typing text.

The guidelines issued by the National Highway Traffic Safety Administration (NHTSA) offer specifics such as ensuring in-vehicle infotainment and communications systems do not divert drivers' attention away from the roadway for more than two seconds at a time, or 12 seconds in total. To expand upon this, the following identifies an emerging list of best practices for the next generation of automotive user interfaces:

- Maximize simplicity
- Minimize number of task steps
- Minimize number of menu layers
- Avoid voice menus
- Disallow typing
- Minimize incoming messages
- Maximize interruptibility
- Minimize verbosity
- Remove need for learning mode
- Minimize speech input
- Minimize glance duration
- Minimize glance frequency
- Minimize task completion time
- Maximize driving performance

A key aspect of rethinking the interaction between cars and people (i.e., the HMI) is to realize that all tasks are not created equal, such as quick retrieval of navigation information in contrast to exploring music choices. Likewise, driver focus also varies widely by age, driving experience, and behavior.[1]

As mentioned, JD Powers and Associates [4] has repeatedly reported that user satisfaction with existing speech interfaces is low, but that users still want it accessible in their vehicles. Therefore, the market is rich with demand, and the time is now to develop an effective solution.

4. THE RESEARCH

In collaboration with the Virginia Transportation Technical Institute (VTTI), Agero, Inc. conducted a visual-speech study [7] comparing participant's coordination of driving while performing simple tasks. The study included 24 Participants (ages 18-30 and ages 65-75 equally); 3 user interfaces (visual & manual, speech only, and speech & visual); and 3 destination entry tasks (address, point-of-interest [POI], and category).

4.1 Objectives

Well-designed human-machine interfaces may help mitigate cognitive distraction for drivers. It is generally accepted that complicated device interfaces with high visual dependencies induce driver distraction during use.

According to research [6], for entering text, speech has proven to be a viable and significantly safer alternative to traditionally visual-intensive methods. For managing short lists, such as selecting an item from a list of options, a visual-manual interface has been shown to be safe and easy to use while driving. Many of the routine tasks associated with driving include entering text and managing lists (e.g., destination entry, music, dialing, and messaging).

The primary objective and uniqueness of the study was to compare and contrast differences in awareness, task performance, and vehicular control for three user interfaces: auditory-vocal, visual-manual, and a multimodal user interface, including vocal, auditory, visual, and touch modalities. The study was structured to use speech for text entry and avoid voice menus. The study was also aimed at comparing the behaviors of younger drivers with older drivers while using the three different interfaces.

4.1.1 Driver distraction variables of interest:

- Task Duration: Critical metric while driving
- Task Accuracy: Success rate at completing tasks
- Speed Measures
  - Mean Speed (mph)
  - Speed Variance (mph)
- Steering Measures
  - Steering Variance (degrees)
  - # of Lane Deviations
  - Time out of lane (seconds)
- Eye Glances
  - Glance Durations (seconds)
  - Eyes Off Road Time (percentage)
- Peripheral Event Detection

[1] Published in The Wall Street Journal, June 3, 2013: http://online.wsj.com/article/PR-CO-20130603-904609.html?mod=googlenews_wsj

  - %Detected/%Missed
  - Latency to Detect
- Workload Ratings
  - Mental Demand
  - Frustration Level
  - Situational Awareness

4.2 Methodology

The On-Road Assessment required participants to engage in nine destination entry tasks, including three visual-manual tasks, three similar auditory-vocal tasks, and three similar multimodal tasks. The destination entry task included the entry of an address, a business name, and a category, as well as the selection of the target destination from a list of the search results (e.g., a particular Italian restaurant). Event detection was also included as a background task performed while driving.

The following metrics were measured: task duration, task success rate, lateral and longitudinal vehicular control, glance duration and frequency, lane deviation, and event detection.

Destinations were entered either by speaking or typing. After entering a destination, a list of search results was presented via an audio-only or visual-manual interface. Based on results from our first VTTI study [6], using speech was shown to be far better than typing text strings manually. However, part of the destination entry process includes having to select a target destination from a list of search results (referred to as results management). To elaborate, destination entry tasks usually require two steps: entering a destination to search for (e.g., an address, POI name, or category), followed by selecting the desired target destination from a list of search results. Although speech input is clearly recommended over typing for the first step, using audio-only for the second step proved to be cumbersome with lengthy task completion times, based on results from the initial study. Instead of using audio (speech and sound) to present and manage the results, we hypothesized and tested that a visual-manual interface could work better. In a convincing manner, the distraction data from the 2nd study clearly showed that mixing speech and vision, when designed properly, yields excellent task and driving performance.

A post-task questionnaire was used to assess workload management. After all tasks were performed, each participant filled out a survey to characterize selected aspects of each user interface tested.

4.3 Results

The visual-speech interface included the following sequence of HMI modalities: a screen tap to initiate the task, an audio prompt to speak, a spoken destination, a search-in-progress prompt, a chime to indicate that the search results have been displayed, glancing, tapping the desired result, and a prompt to indicate task completion. The ordered modalities are: touch, sound, speech, sound, sound, vision, touch, and sound. The data from the study clearly favored the speech interface for destination entry (instead of typing the destination), especially for the elderly. Such an interface can be applied to any secondary task that involves text input followed by a presentation of list results to choose from, such as song names, information categories, or lists with complex items.

The data as a whole slightly favored the multimodal interface (speech-visual). The multimodal and auditory-vocal interfaces were shown to be superior to the visual-manual interface for task success rate, vehicular control, and workload management. The average task duration—which can be directly linked to driver distraction—was lowest for the multimodal interface (as shown in **Figure 2**). The Mean time observed for task duration of a speech-only interface was 55.35 seconds, which is more than twice as long as the speech-visual interface at just 24.67 seconds.

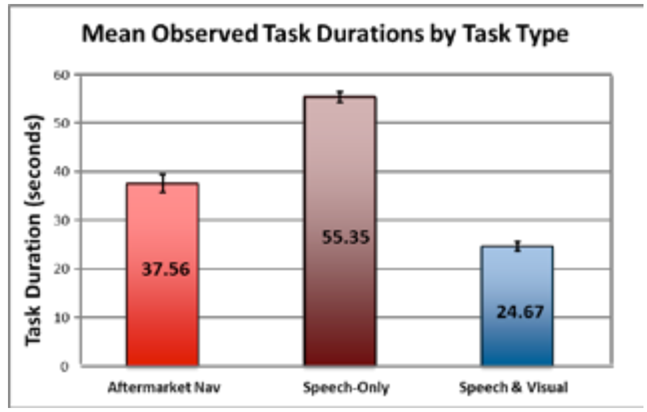

Figure 2. Visual-Speech Study: Task Duration Comparison

The older participants had more difficulty with the visual-manual interface than the younger participants. For the older participants, event detection was significantly impaired while using the aftermarket visual-manual interface, but near perfect event detection was achieved while using the speech-centric interfaces. For the lane deviation measurements, the younger driving segment performed well with the aftermarket visual-manual interface and even better using the speech-centric interfaces. The older drivers had a high number of lane deviations while using the visual-manual device, and a low number of lane deviations while using both speech interfaces. In general, speech proved to help the older drivers perform tasks well and drive well, while keeping the workload management scores in an ideal range. However, both speech interfaces (speech-visual and auditory-vocal) were easy to use by all participants based on vehicular control data and subjective workload management ratings.

Lane deviations, defined as any time where the relevant front tire of the vehicle came into contact with the lane boundary markings, were analyzed and both the frequency and duration of these lane deviations were considered. **Figure 3** shows the mean observed frequency of lane deviations per task by task type and age group. During baseline, the drivers were only performing the event detection task. For all tasks, the younger drivers exhibited far fewer lane deviations than the older. The speech interfaces yielded the best results, especially for the older group.

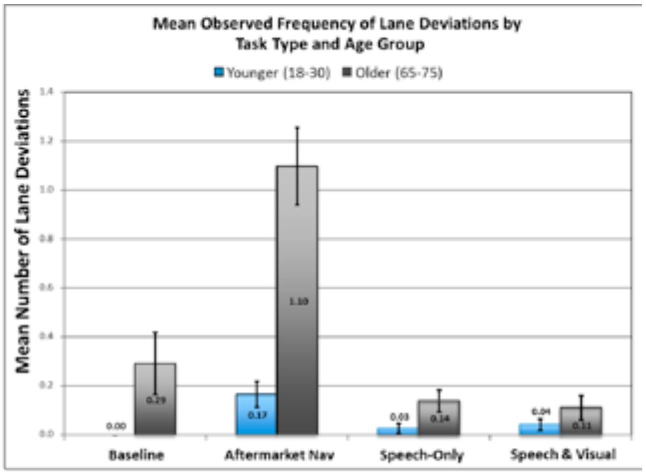

Figure 3. Lane Deviation Frequency by Task and Age Group

Mean observed actual-eyes-off-road (refer to **Figure 4**) was analyzed for each user interface. The Speech and Visual's substantial advantage in task duration over its Speech-Only counterpart accounts for the differences illustrated by the data. The Speech and Visual interface required the least amount of time glancing away from the forward roadway to complete the same task set compared to both the Aftermarket Navigation and Speech-Only tasks. Coupled with task duration, the difference observed between the two speech-based interfaces is also largely due to the increased number of speed-check glances observed during the Speech-Only tasks.

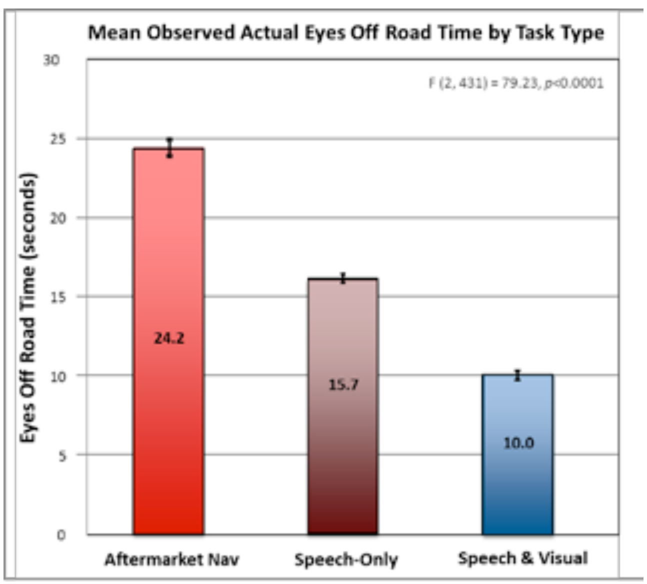

Figure 4. Actual Eyes Off Road Time

Participant ratings for mental demand are shown by task type (scale of 1 to 100, 100 highest) in **Figure 5**. Significant differences were observed across task type, age, and task type by age for ratings of both mental demand and frustration level, as well as by task type for situation awareness. The average scores are shown and slightly favor the Speech & Visual interface.

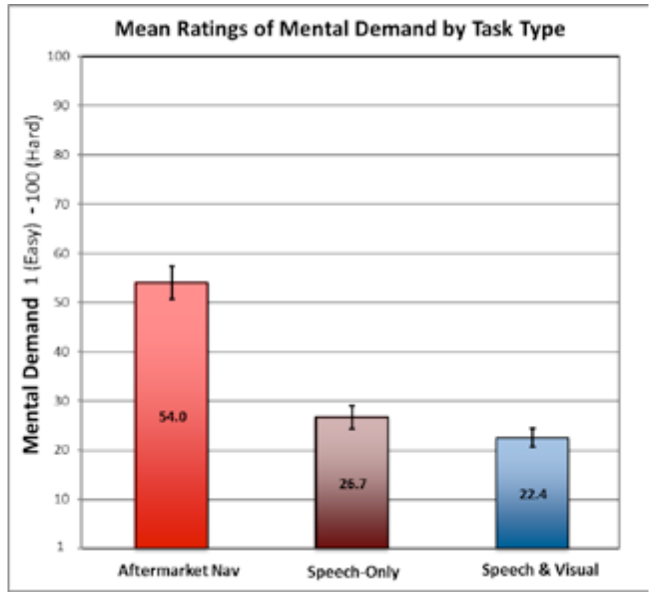

Figure 5. Ratings of Mental Demand by Task Type

A small minority of participants expressed the desire to have the visual-manual interface in their next vehicle. The majority of participants expressed the desire to have the multimodal interface in their next vehicle.

The results show that through the use of a multimodal interface, the task of entering text strings and managing lists of search results while driving can be accomplished safely, and with lower task completion times, when compared to pure auditory-vocal or visual-manual counterparts. The data show that the older drivers benefit more than the young drivers, in terms of task performance, driving performance, and workload management. We concluded that for secondary driving tasks, speech is better for entering text strings, while vision is better for list management [7].

5. CONCLUSION

The conclusions drawn are irrefutable:

- Multimodality in the car is key to usability and safety
- Speech UI in the car needs to be improved
- Speech should be used for text entry
- Driver distraction data supports mixing speech & vision
- The speech button needs to integrate with the touch screen or other HMI components

Based on our research and our evaluation of solutions in the market, we propose a blend of technology and thus recommend use of multimodal interfaces. **Figure 6** shows that Entry tasks should use modes such as gesture, speech, and touch toward communication to the device (in this example the vehicle head unit or display). The presentation of information should then be provided as a blend of visual display (for quick glancing or tapping), sound (audio prompts or chimes), and haptic (vibration feedback). This blend of interactive modalities combined with the Tap-or-Say approach should bring an amazingly simple and effective in-vehicle user experience.

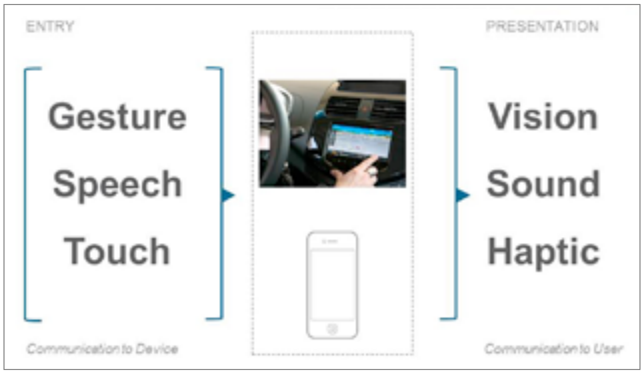

Figure 6. Entry Modes v. Presentation Modes

6. Acknowledgements

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Exploring the User Experience of Autonomous Driving Workshop at AutomotiveUI 2013

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ABSTRACT
Although cars are not flying yet, self-driving cars are definitively closer than some may think. Numerous research organizations and major companies have developed working prototype autonomous vehicles. Three U.S. states have passed laws permitting autonomous cars on public roads and the UK is currently working on making similar policy changes. Technical challenges are of great importance to fully transition to these vehicles, but legislation, infrastructure and human factors elements are of equal significance to tackle, and have received much less attention. With this workshop, we would like to start the conversation of Autonomous Vehicles with experts and researchers specifically in the area of Human Factors and User Experience. This workshop will explore the emerging themes of autonomous driving, social driving and novel user interface approaches. The aim being to define the future landscape for research within and across each these areas.

Categories and Subject Descriptors
H.1.2 [User/Machine Systems]: Human Factors, Human Information Processing.

General Terms
Human Factors, Experimentation, Design, Measurement, Human Computer Interaction, Verification.

Keywords
Autonomy, Autonomous Vehicles, Human-Autonomy-Interaction, User Experience Design and Research.

1. INTRODUCTION
Marc Hassenzahl stated that a common feeling exists today amongst vehicle and transportation researchers where "most technologies are driving-centered; the remaining are entertainment technologies (e.g., music, radio, games) or "traditional" communication technologies, such as the telephone. Likewise, interaction design in cars focuses mainly on the driving task and safety issues" [6] thus leaving lots of potential areas unexplored. Furthermore, the increasing success of researchers within the field of autonomous cars (also known as robotic cars, or informally as driverless or self-driving cars) means there is now the option to provide advanced services in cars while the vehicle is under fully automated or semi-automated control. Indeed it is widely predicted that automated driving will become more widespread in the near future [2]. This is perhaps best illustrated by the fact that numerous research organizations and major companies have developed working autonomous vehicle prototypes, including Mercedes Benz, Google, Bosch, Nissan, Toyota, Audi, among others. Indeed BMW expects to see "highly automated" driving functions available in its models by 2020 [8]. The subject is also being taken seriously at government level with three US states already having laws [9] and the UK planning to introduce them by the end of 2013 [1].

The most recent definition of California's DMV defines autonomous vehicles as "any vehicle equipped with autonomous technology that has been integrated into that vehicle" [3]. Another common definition of autonomous cars is a "vehicle capable of fulfilling the human transportation capabilities of a traditional car … capable of sensing its environment and navigating without human input [5]". While The National Highway Traffic Safety Administration[1] extends this by providing five levels (zero to four) of automation these are: (0) No automation, (1) Function Specific Automation (2) Combined Function Automation (3) Limited Self-Driving Automation and (4) Full Self-Driving Automation. Each provides for an ever increasing degree of

[1] http://www.nhtsa.gov/

automation and with it a set of new challenges in terms of supporting automated driving. The increasing scale also opens up the potential to explore new services and user interface technologies.

Autonomous cars are not the only challenge being faced by industry and researchers. Indeed the plethora of new media, services and devices which can exist within car environments either for use by the drivers or passengers, including those which combine these elements into gamified environments such as VW SmartDrive and traffic congestion reduction approaches suggest a need to radically re-think the way we conceive the in-car experience. Indeed until comparatively recently the idea of drivers playing "games" in cars or engaging in micro-entertainment would have been largely outside the scope of what was considered acceptable from a safety perspective. These new experiences often require the exploration of novel interface techniques such as haptics, natural user interfaces, auditory or subliminal cues. Yet, to date the car itself remains comparatively bereft of these new approaches on account of the quite rightful set of safety considerations.

This workshop will aim to collect different, radical, innovative, versatile and engaging works that challenge or re-imagine human interactions in today's automobile space. It will seek to challenge existing thinking by exploring what is possible both now and by the time the autonomous vehicle is a standard feature of our roads. Participants will be encouraged to suggest alternative concepts whether low fidelity, high fidelity, or both. Especially encouraged will be works that are experiential and can be demonstrated hands on. The workshop will be an opportunity to re-shape the conversation of automobile technology by introducing the community to a new way of thinking. We will include questions on user acceptance and trust [4] as well as the role of insurance companies [7]. Topic areas of potential interest (not exhaustive) include:

- Autonomous vehicles, including specific issues such as handover, legal, ethics and trust
- Novel user interface approaches from haptics to subliminal information
- Usability testing and user acceptance, including metrics and analysis approaches.
- The social car, from a current human centred social networks perspective to one where cars have greater control.
- Entertainment for drivers and passengers, including gamification.

2. WORKSHOP STRUCTURE

The proposed format for the workshop consists on a full-day session. The workshop will be made up of presentations, discussions, and a hands-on activity.

2.1 Detailed Schedule

9:00 – 10:30 –Participants will introduce themselves as well as his or her interest, experience, and perspective on the topic and current research, if available.

During this time, each participant will be asked to rank the proposed areas of discussion (as listed in the introduction, that will also be provided to participants prior to the workshop). The collectively top 4 ranked areas will be further addressed during the workshop.

10:30 - 11:00 -Coffee Break

11:00 - 12:00 –First Group Session. A discussion of two major topics identified.

12:00 – 1:30 – Lunch

1:30 - 2:00 –Second Group Session. A discussion on two further major topics.

2:00 - 3:30 - Hands on Activity (in small groups)

The goal of the activity will be to produce a concept, solution, or thoughtful point of view to be presented to the group. The activity will follow a rapid design approach. Required materials will be provided by the organizers.

3:30 - 4:00 -Coffee Break

4:00 - 5:00 –Each small team will share the concept with the group and a discussion will be encouraged.

6:30 –After Workshop Dinner (TBD)

3. WORKSHOP AUDIENCE

We would like to invite practitioners and academics from a range of disciplines, including design, marketing, anthropology and ethnography, sociology, engineering, and computer science. We would aim for a workshop of approximately 16 -20 individuals with a good representation of different disciplines. Registered participants will be contacted to prepare a short biography as well as their motivation to join the workshop before hand, but they will NOT be required to submit a position paper. Details will be communicated within the call for participation.

A website, listing pertinent dates and distributing information, will be set-up by the workshop organizers. This website will be used for publicizing the workshop amongst peers in the academia and industry as well as to share any pertinent research and information on the topic. The call for participation will be distributed via HCI, UX and Automotive UI related mailing list (e.g., chi-announcements). We will further use our own/personal distribution lists and social network.

4. EXPECTED OUTCOMES

We aim to help engaged participants to develop their provocative ideas and express them clearly. These ideas then provide new angles from which to understand the field. This increase in perspectives, coupled with a confidence that a good idea will eventually form itself into a practical mainstream solution, increases with richness of thinking within the community. Additionally, we aim to create a collection of such works and distribute it in appropriate channels such as publications in journals or interest. One venue could be Interactions (ACM), as an example. We also aim to build a network with and for the attendees (and those with similar thinking) to rely on each other and further collaborate on their novel ideas.

5. ORGANIZERS BACKGROUNDS

Manfred Tscheligi is Professor for the HCI & Usability at the University of Salzburg and was Conference Chair for the 3rd Conference AutomotiveUI 2011. David Wilfinger, Research Fellow, and Alexander Meschtscherjakov, Assistant Professor, together directs the car team at the HCI & Usability Unit at the University of Salzburg. Carlos Montesinos and Dalila Szostak are researchers at the Interaction and Experience Research

Laboratory, Intel Labs, currently focusing in the area of transportation. Rod McCall is the leader of the IGNITE (Interaction, Games and Novel Interface Technologies) research collective at SnT, University of Luxembourg. Rabindra Ratan is an Assistant Professor at Michigan State University's Department of Telecommunication, Information Studies, and Media. Alexander Muir is Senior Design Researcher in Microsoft Corporation's Connected Car division, leads the UI Research efforts to explore and assess the next generation of infotainment experiences.

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Message from the Workshop Organizers

Welcome to our second workshop, "Socially-inspired Mechanisms for Future Mobility Services" at the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2013).

Researchers and practitioners have recently started to think more seriously about the topic of socially inspired car and this is reflected in several big projects just launched. From that background, and based on the findings from the AutoUI 2012 workshop on the same topic, this workshop aims to provoke an active debate on the adequacy of the concept of socializing cars, addressing questions such as who can communicate what, when, how, and why? To tackle these questions, we invited researchers and practitioners to take part in an in-depth discussion of this timely, relevant, and important filed of investigation. We expect that the approach provides exciting challenges, which will significantly impact on an automotive community at large, by making significant contributions toward a more natural and safe communication within a car and between cars.

There are several on-going research projects regarding car-to-car services, but certainly many more inputs are needed to implement robust car-to-car services and environments. We believe that this attempt could be a basis on further research and enrich this growing research domain in automotive user interface contexts.

In conclusion, we greatly appreciate all the authors, participants, and reviewers for their contribution to shaping this workshop. Enjoy the workshop and the remaining conference!

Andreas Riener,
Myounghoon "Philart" Jeon,
Ignacio Alvarez

WORKSHOP at AutoUI 2013 "Socially-inspired Mechanisms for Future Mobility Services"

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ABSTRACT

Research on next generation automotive ICT is challenged by the complex interactions of technological advancements and the social nature of individuals using and adopting technology. Traffic in the future will no longer be considered as a network of individually behaving "dumb" cars, but rather as the entirety of social interactions between its entities. Successful application of collective, socially inspired driving mechanisms requires to understand how socially-inspired vehicles (i.e., driver-car pairs) could make use of their social habitus, composed from (past and present) driving behavior, social interactions with pedestrians, vehicles, infrastructure, etc., and drivers' vital states when exposed to other road participants in live traffic. In response to this emerging research direction, the aim of this workshop is to achieve a common understanding of the symbiosis between drivers, cars, and infrastructure from a global point of view (referred to as "collective driving"). In particular, this workshop is expected to provoke an active debate on the adequacy of the concept of socializing cars, addressing questions such as who can communicate what, when, how, and why?

1. "The Social Car"-Workshop at AutoUI 2012

Recently launched big projects reflect researchers' and practitioners' serious interests in socially inspired cars. From this background, our previous workshop, "*The Social Car: Socially-inspired C2X Interaction*[1]" at AutomotiveUI 2012, was the first attempt to discuss this timely, relevant, and important field of investigation. Preliminary findings showed exciting potentials of this approach, which would significantly impact on the automotive community, by making contributions to a more natural and safe communication within a car and between cars. In the following, we provide a short summary of the outcomes of the first workshop and other papers at AutomotiveUI 2012 devoted to this topic.

1.1 Socializing cars » current state

With everywhere Internet connectivity and broad penetration of social networks, SNS have also emerged in the automotive domain. Social services provide a basis for allowing cars to share sort of social information (e. g., feelings and emotions) amongst other vehicles, for example by taking information from diagnostics systems, on board sensors, and live traffic information into account. The potential is enormous, given the number of cars on the road worldwide (currently more than one billion units, with expected growth to 1.5 million in the next 10 years). To infer the plausible distraction in such a highly connected setting, Lee and colleagues [6] showed computational models of driver behavior. Schroeter *et al.* [11] discussed the challenges and opportunities that place and time-specific digital information may offer to road users. They summarized findings from an on-the-road experiment conducted with the overarching goal to identify room for improvements to make driving safer and more enjoyable. Riener's [7] visionary concept of driver-vehicle confluence aimed at understanding the symbiosis between drivers, cars, and (road) infrastructure, which includes reasoning about driver states and social or emotional interaction. This in-car service could be achieved by modeling driver behaviors, studying distributed negotiation processes, performing driving studies and simulations, and relating their results to observations made in reality. To extend on this, the authors of [9] outlines several sample scenarios to accentuate the potential beneficial effects of the application of driver-vehicle confluence on future traffic.

The workshop "The Social Car: socially inspired C2X interaction" [10] discussed the potential of cars' socializing one with the other (similar to how humans are exchanging information), and aimed to make a blueprint of next generation in-vehicle technologies. Some workshop papers contain more macro-level perspectives about social cars – Chiesa [10, p. 35ff] suggests researchers carefully translating the current networking practices into the new social environment, going beyond merely posting pre-set messages on Facebook in a car. In [10, p. 25ff] , Diewald *et al.* discusses an integrated transportation service platform called "MobiliNet", which provides a blueprint of how overall vehicle-area-network services could be arranged in a single platform. Applin and Fischer [10, p. 39ff] propose "PolySocial Reality", a conceptual model of the global network environment among drivers, passengers, pedestrians, and locations. A series of papers discuss intra-car collaborations. Perterer [10, p. 11ff] conceptualize driving as a social activity or collaboration between a driver and a passenger, Ratan [10, p. 31ff] describes an in-vehicle agent, but explores different types of drivers' perception about their car: avatar (as an extension of the self) versus robot (as social entity or a partner), Son and Park [10, p. 21ff] show empirical research on age and

[1]https://www.pervasive.jku.at/AutoUI12_SocialCar/

gender differences in acceptance and effectiveness of a intelligent warning system. Two papers emphasize more on how to practically design social car services, especially involving users in the iterative design process. Jeon [10, p. 45ff] provided young drivers' needs analysis about plausible vehicle-area-network services based on vivid qualitative descriptions. Tan and colleagues [10, p. 17ff] introduced a "Jumping Notes" application that could be used in a jam.

1.2 Socializing cars » future proliferation

To develop the future of socially inspired traffic, we focus on in-vehicle social interactions, by exchanging available data from on-board information systems, driver states, and parameters gathered from the infrastructure. For example, it would be relatively easy for a vehicle to continuously stream status information (e. g., driving speed, position, destination) by wiretapping on-board information systems and navigation devices. Furthermore, a car could provide information about its "health" by taking information from diagnosis systems such as the engine control unit (ECU) or powertrain control module (PCM) (e. g., error codes, condition of engine, tire temperature, oil pressure, etc.). Last but not least are non-invasive tracking devices available (capacitive ECG's, thermal cameras, pressure sensors in the seat, skin conductance sensors in the steering wheel, etc.) that allow for driver social/mental state detection. Related issues include:

- **Car-to-Driver Relationship**: A car can (i) "learn" a jam every workday on a certain road, and then, the car would recommend an alternative route, (ii) "remember" a road sign with a certain speed limit and/or cold temperature outside (i. e., ice on the road) while driving through a sharp turn (e. g., "Route Buddy", "Sensory Bubble" concepts [4], [5]); and (iii) "forget" the accident previously happened after some time (e. g., after the winter has passed). This social behavior should avoid a car being fearful and driving too slow on the same road in summer.
- **Car-to-Car Relationship**: Cars in the vicinity, same route or destination can give and take information, such as a speed warning on icy road ahead, reroute recommendation on traffic jam, or blocked route, etc. It can also facilitate car sharing or car pool services.
- **Car-to-Infrastructure Relationship**: A social car concept would require social environments (just as humans need social environments) including the car-to-infrastructure relationship as well as the car-to-driver and the car-to-car relationship. For example,
  - "*Smart road concept*": Dynamic reconfiguration of the road network by changing lanes per direction inbound/outbound depending on time of day or road usage,
  - "*Smart signs concept*": Changes the speed limit based on the context (e. g., reducing when novices approaching or increasing when professional drivers approaching; an "overtaking denied" message is popping up on a detected big truck or traffic jam, etc. In the curve ahead, "overtaking permitted" is shown if the sign detects no other car in that area ("Intelligent Traffic Guide" concept [4], [5]).

Assessment

The potential is enormous, given the amount of cars on the road worldwide (which is even higher compared to the number of active Facebook users). The aim of the workshop goes beyond "just presenting Facebook updates" (or social media in general) to the driver which has, in our comprehension, a great potential. To outline one possible (maybe the most primitive) application scenario, with socially inspired car-to-car interaction automatic driver assistance systems would have the foundation to autonomously communicate and negotiate with each other car without driver involvement.

The central objective is to provoke an active debate on the adequacy of the concept of socializing cars. The workshop topic raises elementary questions (e. g., 5W1H), including who can communicate what, when, how, and why? To tackle these questions we would like to invite researchers to take part in an in-depth discussion of this timely, relevant, and important field of investigation.

2. Organizers bios

Andreas Riener

is a postdoctoral research fellow at the Institute of Pervasive Computing at the University of Linz (Austria). He has more than 60 peer reviewed publications in the broader field of (implicit) human-computer interaction and context-aware computing. His core competence and current research focus is human vital state recognition from embedded sensors, multimodal sensor and actuator systems, context-sensitive data processing, and socially-inspired implicit interaction influencing the driver-vehicle interaction loop. Andreas is member of the Austrian Computer Society (OCG), IEEE Member, and member of the Human Factors and Ergonomics Society (HFES), Europe Chapter.

Myounghoon "Philart" Jeon

is an assistant professor in the Department of Cognitive and Learning Sciences at Michigan Tech. His research areas encompass auditory displays, affective computing, assistive technology, and automotive interface design. His research has yielded around 60 publications across various journals and conference proceedings. He received his PhD from Georgia Tech in 2012. His dissertation focused on the design of in-vehicle emotion regulation interfaces using auditory displays. Previously, he worked at LG Electronics and was responsible for all of their automotive UIs & sound designs.

Ignacio Alvarez

is currently research assistant at the Human-Centered Computing Lab in Clemson University focusing on Automotive User Interaction design and its relation to driver distraction. Furthermore he is project manager in BMW for Connected Drive and Innovations for the Asia Pacific Area, where he directs the development of vehicle telematic functions for driver assistance, security, infotainment and location based services. He obtained his PhD in Computer Science and Artificial Intelligence at University of the Basque Country in Spain in 2012. His dissertation focused on the development of natural vehicle voice interfaces adaptive to the driver distraction level.

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Necessity of Vehicle to Rail Infrastructure Communication for Grade Crossing Warning & Safety

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ABSTRACT
Vehicle area network (VAN) services have been launched in the U.S. and EU with a focus on vehicle-to-vehicle (V2V) interactions. However, V2V is not the whole story of the VAN concepts. As a case study of vehicle-to-infrastructure (V2I) communication, this position paper tries to show the necessity of vehicle-to-rail infrastructure networking with respect to the warning system at grade crossings. After describing the challenges of the current warning systems at grade crossings, we delineate a series of research plans about the possibility of the use of in-vehicle auditory warnings, plausible distracters, and the optimization of the information via V2I communication, which will lead to the ultimate conclusion of the necessity of V2I communication. We hope that this paper could contribute to the extension of the VAN concept and facilitate a debate on this topic in the Automotive UI community.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces – Evaluation/methodology, Interaction Styles (e.g., commands, menus, forms, direct manipulation), Auditory (non-speech) feedback, Voice I/O, User-Centered Design

J.4 [**Computer Application**]: Social and Behavioral Sciences – Psychology

General Terms
Design, Experimentation, Human Factors

Keywords
Auditory warning; grade crossing; VAN (vehicle area network); vehicle-to-infrastructure communication

1. INTRODUCTION
With the advances of networking technologies, people experience literally "seamless services" in any contexts, including their home, workplace, or even on-the-go. This trend is also pervasive in a vehicle domain, which leads to what we call "vehicle area network" (VAN) or social car research [1]. Fairly recently, a couple of big projects about VAN services have been launched with a focus on vehicle-to-vehicle networking (V2V) [e.g., 2, 3]. However, V2V is not the only one consideration of the VAN concepts, but VAN services can be classified into four categories: IV (Intelligent Vehicle), V2V (Vehicle-to-Vehicle), V2B (Vehicle-to-Business), and V2I (Vehicle-to-Infrastructure) [4]. The present paper focuses on V2I. To illustrate, V2I can include an intelligent traffic guide that helps drivers to decide "stop or go" on the yellow light. Free parking slot finder is another example of the V2I service. Drivers can get customized infomercial (information + commercial) fitting to their situations even though it also seems close to V2B. For more examples of VAN services, see …….[5].

We propose the vehicle to rail infrastructure communications to improve highway rail at-grade crossing safety. Fatalities that take place at highway grade crossings (together with trespasser fatalities) form the great majority of rail related fatalities annually. Given that human errors account for more than one third of all train accidents in the U.S. [9], one of the potential approaches to reduction of grade crossing fatalities and accidents may be to provide drivers with optimized warnings and to decrease a chance for missing warnings. Currently, there are two main types of warnings to drivers in the highway grade crossings; visual and auditory warnings. Given that drivers' vision is already heavily taxed while driving, auditory warnings may hold greater potential to improve driver safety.

To demonstrate the necessity of V2I in this grade crossing context, Michigan Tech has planned a series of research activities to investigate the effects of auditory warning cues on driver behaviors at rail crossings and explore optimal alternative designs to compensate for the issues of the current warning systems via vehicle-to-rail infrastructure communication. When it comes to a constituent of V2I communication in grade crossings, it can include drivers (or the in-vehicle systems), locomotive cab operators, and grade crossing systems. The three phases of research include: (1) comparing the effects of warning types (visual, traditional auditory, and novel in-vehicle auditory warnings) when approaching the rail crossings, (2) analyzing the interaction effects between auditory warnings and auditory distractions at railroad crossings, and (3) designing optimal auditory warnings by considering warning sources, timings, and appropriate contents.

2. CHALLENGES AND NECESSITY OF

V2I FOR GRADE CROSSINGS

Under current practices, railroads sound locomotive horns or whistles in advance of grade crossings [6]. Under the Federal regulation, locomotive engineers must sound train horns for a minimum of 15 seconds, and a maximum of 20 seconds, in advance of all public grade crossings. Grade crossings with active warning devices (gates and lights) have also bells as additional auditory warnings. One of the current auditory warning issues is that it has multiple exceptions (e.g., if a train is traveling faster than 45 mph, if a train stops in close proximity to a crossing, or when engineers can't precisely estimate their arrival at a crossing, etc). In these exceptional cases, the auditory warning convention might be different or could even disappear. Moreover, local governments or public agencies are able to establish "quite zones", which are equipped only with conventional visual warning devices such as flashing lights and gates. Therefore, a supplemental auditory warning is necessarily required for this situation. On the other hand, the traditional auditory warnings at rail crossings could be masked by varied distraction sources, such as in-vehicle music, speech with passengers, or phone calls. Based on this background, in-vehicle auditory warnings at grade crossings can be an alternative approach to reduce grade crossing fatalities and accidents, making vehicle-to-rail infrastructure communication necessary.

3. ON-GOING PROJECTS

3.1 Warning Types

First, we will determine the incremental effects of auditory warnings including both novel in-vehicle signals and traditional train horns and crossing bells, in addition to visual warnings for the driver when the car is approaching rail crossings. Some navigation devices (e.g., TomTom, Garmin, etc.) provide a visual symbol about the rail crossings, but they do not provide auditory warnings. Auditory researchers have applied a number of auditory cues to the in-vehicle contexts (e.g., speech cues, auditory icons [7] – representative part of sounds of objects or events, and earcons [8] – short musical motives as symbolic representations of objects or events). However, there is still a debate about the best auditory cue. This study compares all of those types of auditory cues at a variety of crossing types and sees whether in-vehicle auditory warnings can equal or improve conventional ones. Drivers will complete a simulated drive that will include a series of rail crossings with diverse auditory cues.

3.2 Distraction and Masking

Next, we will assess the effects of auditory distractions on drivers' ability to recognize railroad crossings in advance and prepare for it accordingly. Plausible in-vehicle auditory distractions will include sound-based (music), speech-based (news), and cognitive-based (cell-phone conversation) ones. The intent of this study is to understand what type of auditory warnings (traditional ones and various in-vehicle ones) at crossings are less masked by auditory distracters and more effectively alert distracted drivers.

3.3 Optimization of Warnings via V2I Networking

Finally, we will explore more specific details of auditory warnings. Currently, train horns must be sounded in a standardized pattern of 2 long, 1 short, and 1 long and the horn must continue to sound until the lead locomotive or train car occupies the grade crossing [6]. Taken the results of the previous phases, optimal warning alternatives will be designed and tested in terms of auditory cue types, sources, and timings (when to provide auditory cues and how many warnings to provide). In this phase, we are specifically interested in warning contents (e.g., how to synchronize the warning with the arrival to the rail crossing with the current car speed, whether there is an approaching train, where the train is coming from, etc.). Some of the information should be obtained via the communication with locomotive operators or grade crossing systems. We are also interested in measuring drivers' perceived performance and subjective safety in addition to objective performance in their readiness.

4. CONCLUSIONS & FUTURE WORKS

This research will provide a deeper understanding of how drivers can be more effectively prepared to approach railroad crossings with newer types of auditory warnings, and that could be possible only with appropriate V2I communication. As an outcome, this research can also inform the decisions on how to design optimized auditory warnings and when to provide drivers with critical auditory warning information. The timing and the range (i.e., trigger zone) of the communication and who is in charge of communication (e.g., driver and operator or in-vehicle – i.e., automation) need to be further addressed.

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Cards as design tools for the "Social Car" domain

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ABSTRACT
In this paper, we present our "Social-based Services for Mobility" card deck, as a powerful tool for brainstorming sessions and design inspirations, focused on the 'Social Car' domain.

Categories and Subject Descriptors
H.3.5 [**Online Information Services**]: Web-based services

General Terms
Design, Human Factors.

Keywords
Car, social car, social-based services.

1. INTRODUCTION
In the initial phase of our collaborative research project AUTUMN2 - AUTomotive hUman Mobile Network 2 – our group was mainly focused into the exploration of new ideas, concepts and paradigms about social-based services for the automotive domain. During the activities we collected a huge amount of data, material and notes about existing services, users' wants and needs, typical users' scenarios, etc. Then, one of the project's goals was re-defined as the implementation of a set of services, or a meta-service, rather than the implementation of a single, vertical, narrow service for a single need/scenario.

For this reason, we went deeper into the analysis of possible correlations, overlapping, integrations and mutual interactions among what discovered until that moment. We understood that a card deck could be an useful tool to communicate initial results, engage users, stakeholders, other designers and researchers in further brainstorming sessions and design. We discovered through the use that it helps especially in the discovery of unexpected interactions and relationships between different scenarios, and more.

2. CARDS CATEGORIES
During the initial phase of the project we explored, without limitations, a huge set of possible scenarios for automotive/mobility services, considering several patterns and behaviors, from commuters to tourists, from young drivers to elderly people, from existing services to futuristic ones.

Explorations went through brainstorming and bodystorming sessions, observations, interviews with actual drivers, personal logs. After some clustering sessions, we organize 40 cards into four main categories:

Driving, Parking, Commuting, Identity.

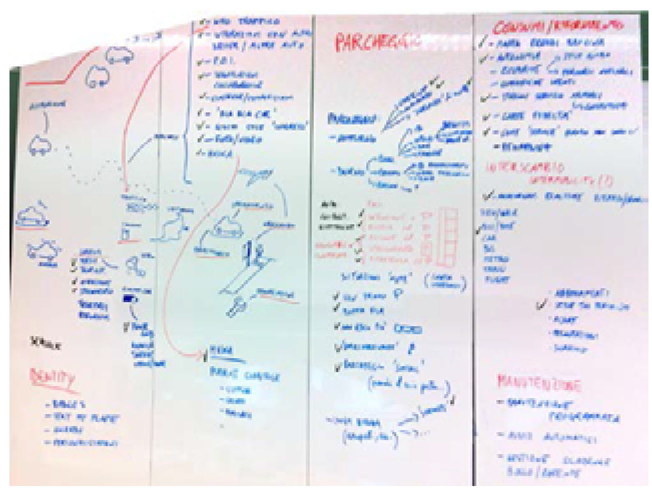

Figure 1 - A shot caught during one clustering session

Temporal and functional relationships were the main criteria for the affinity diagram built during clustering sessions, with the aim of 'covering' the largest possible spectrum of scenarios, within a typical all-day-long usage, or for special occasions.

In 'Driving' we consider all the services, scenarios or needs that happen while driving. In 'Parking', services, scenarios or needs that happen while the car is parked. The category 'Commuting' refers to services especially focused on the interaction with other transport systems, like metro, bus, bike, etc. Finally, the 'Identity' category

3. CARDS LAYOUT AND CONTENT
3.1 The back side
On the back side, a picture suggests and shows the theme/service described by the card itself. A colored strip defines the category of

the card, together with an icon, and contains also the title for the service.

3.2 The front side

On the front side, cards layout are split in three main areas.

In the first area, each card shows a brief description of automotive/mobility - related possible service, while in the second area (with reversed colors) shows a sample of a possible interactions of the users with the service itself.

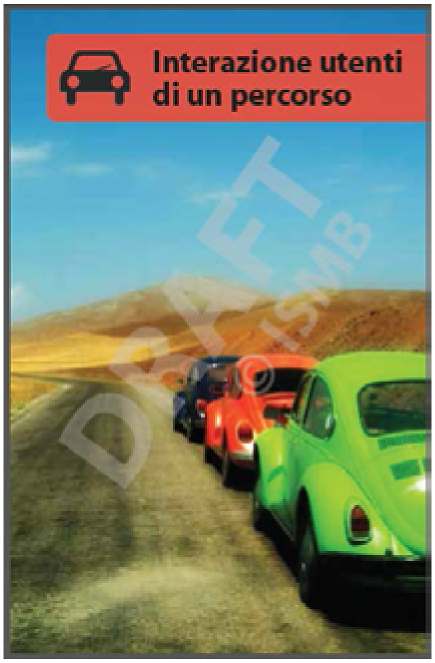

Figure 2 - Back side of a sample card

Figure 3 - Front side of a sample card

Above being framed with the color of the category (Driving, Parking, Commuting or Identity), a third area highlights for each card which basic functions (between Social, Award, Location, Time / Schedule, Media Sharing and Rating) are needed for that service / scenario.

4. CARDS ITEMS

Here's the list of scenarios / services for each card:

4.1 Driving

30 Info traffic
38 Interactions with drivers on the same route
36 P.O.I.
32 Collaborative alerts
22 Driving style competitions
24 Best route sharings
10 Location-based services
14 Photo/video sharing
26 Music and playlist route-related
28 Gas stations and prices
6 Vehicle autonomy
2 Meteo forecasts
18 Payments management
41 Follow Me
34 Start engine

4.2 Parking

13 Stop engine
25 Night Check-up
35 Anti-thief systems
23 Willing to park
1 Search for a free parking slot
5 Parking ticket payment
17 Can't find to park
31 Parking troubles
29 I'll park your car
37 Take my place
33 Power grid
21 Services during parking
9 Planned amintenance
27 Booking services
40 Deadline management

4.3 Commuting

3 Realtime timetable updates
11 Routes and crossings

15	Car sharing
39	Car pooling
7	Bike sharing
19	Bus to call

4.4 Identity

16	Fidelity cards
12	Badges
20	Actual Awards
8	Car plates identities
4	Tuning e customisations

5. CARDS AS A DESIGN TOOL

In a second design phase, we used the cards as a design tool, to help and stimulate discussions and animate creative sessions.

The whole deck is constantly updated from one creative session to another, allowing researchers to modify some cards, add new cards, join two or more cards in a single one, split a card into more cards, etc.

We have also ‘blank’ cards to allow participants to add changes during the sessions themselves, and not only at the end of the creative session, during the debriefing.

The cards were particularly useful for: discovering unexpected interactions and relationships between different scenarios; for warming-up brainstorming sessions and help participants to start talking about their personal experiences and real-life anecdotes; for eliciting actual motivations, opportunities and advantages for users to register themselves in social-based mobility services and actively use and co-create them.

Figure 4 - The card during a creative session

Another interesting application for the card deck is for implementing serious games with users and volunteers. We defined several serious games, to go even deeper in the explorations.

5.1 Serious games

A Serious Game is a game designed for a primary purpose other than pure entertainment. As design tools, played by individuals or by teams, Serious Games can be applied to generate a broad range of innovative solutions. They can help understand and explain complex scenarios via principles of gaming, engaging participants through competition, teamwork, intrigue, curiosity and problem-solving. This attracts participation, encourages creativity and helps establish a path to collaborative work and analysis.

We conceived several mini-games to support and stimulate idea generation during the creative sessions. We named these games with labels like ‘Pick 4 and discard 1’, ‘Pick 3 and replace 1’, ‘Pick 3 and trade 1’, ‘Texas Hold’em’, etc.

Here it is a brief description of the 'Pick 4 and discard 1' mini-game: the dealer gives 4 cards to each participant. The players have 1 minute to reflect on their own and decide which card to discard. Each player has then 1 minute to describe a service, able to contemplate and use all the 3 cards still in his/her hand: what needs to respond, in what contexts, for which users, through what process, etc.

At the end, other participants have 2 minutes to debate, ask questions, make comments. Once everyone has done his/her choice, the dealer gathers the cards and shuffles them for the next round. As a competitive option: at the end of each round, the dealer or - alternatively - all participants assign a point to the player who conceived and described the more compelling service.

6. CONCLUSIONS

We want to go beyond "just presenting Facebook updates" (or social media in general), and outline tangible benefits and reasons for the “Social Car”. Serious gaming can really stimulate designers, stakeholders and other participants in challenging tasks and in design competitions.

We would like to present to other workshop’s participants our tool, let eventually use them in short creative sessions and hopefully actively contribute to the workshop. A special version of the cards, in English, will be available on time for the workshop itself.

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Socially-inspired Driving Mechanisms

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ABSTRACT

Today's cars include plenty of technology, however, they are still mindless and need to be controlled by an individual. As each and every driver has its own personality and the internal state of a driver may change from one moment to the next, this individuality is affecting vehicle movement on the road, leading to an unpredictable and unsafe movement behavior. Looking into the future of traffic, which is expected to be shaped by (gradually emerging) self driving cars, a safe (and effective) coexistence would require social interaction, collective negotiation, and concerted (re)action between all the entities (i. e., manually controlled cars and autonomous vehicles). This position paper aims to identify problems and highlight possible solutions in this regard.

1. SOCIAL PRINCIPLES IN TRAFFIC

Social interaction in the car domain has up to now be provided only on individual level. Technical advances affecting vehicle handling (e. g., power steering, assisted braking, etc.) and driving comfort (route guidance, driving assistance, on board entertainment, etc.) have led to a strong(er) interrelationship between the driver and the technical systems in a car [4]. With latest achievements in wireless communication technologies the whole new class of vehicle-to-"x" applications allows now spontaneous formation of car collectives or *cooperative crowds* to offer services and applications on car-to-car, car-to-roadside, and car-to-infrastructure levels. The critical question here is, however, if the information technology available in the car actually allows for "real" social behavior in networks of cars. According to [5], social aware cars (with abilities and intentions for adaptation) have to cope with individual and group behaviors and goals. The basic entities of such a system are many local actors (driver-car pairs) with 1) *individualism* (habits, customs, character, daily routine, (un)consciousness, personality, emotions, cognitions, physical states, intrinsic and extrinsic behaviors), *restricted perception* of their environment, and a limited *capacity of action* as well as 2) *collectivism* (social grouping, long and short term social behaviors, social practice, both prejudices and tolerance, fashion, tradition, social etiquette). What has been observed so far is that most of the stated principles have been seriously neglected in present systems and that also ethics need to be built-in in any solution in order to provide ethical sensitivity to each of the above aspects. To approach an answer for *individualism*, a number of (social) criteria characterizing human behavior and/or reputation need to be validated. Attributes to consider include the ability to communicate and interact, willingness to negotiate, own cognitive abilities, self-manage behavior history, good/bad reputation, judgment, ability to assert oneself, forget/forgive, rapid assessment and decision making, and learning/adaptation capabilities. With regard to *collectivism*, cars are socializing to achieve a global optimum (*the goal*) based on a cost (fitness) function that concerns the environment of the problem in its totality. The difficulty in traffic is, that different time scales are evident (driving action: seconds, emergence of a jam: minutes to hours; change of weather: hours to days; legal regulations: month to years), that driving is a highly dynamic task (negotiation, re-distribution of the decision to local actors, behavior adaption, etc. is often not possible in the due time), that there are many (local) actors with maybe individual behavior, restricted perception of their environment, and a limited capacity of action involved, and that the context and its boundary conditions are continuously changing (traffic situation, jams/accidents (driver fell asleep), infrastructure failures (traffic lights), weather conditions (dry to snow storm), etc.) [1] [2]. Furthermore, in order to provide stable solutions (interplay of *individualism* and *collectivism*) it is required to perfectly understand the reality to be faced, i. e., the context and its boundary condition in which the scenario is embedded into.

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1.1 Evolution of Social Interaction in Traffic

Cars may have become "smart" during the last time, but still they are mindless and need to be controlled by an individual. Each and every driver has its own personality and the internal state of a driver may change by different reasons from one moment to the next. And this is, of course, a source of unpredictable and unsafe behavior. Legislatory regulations and traffic control can prevent danger caused by alcohol, drugs, maybe fatigue, but there are other sources that (temporarily) influence the normal competence of a driver that might not (yet) be detected reliably by technology (for example, stress, anger, or rage). Before establishing vehicle-to-X communication on broad scale (and with it, enable self-driving on larger scale), the before mentioned problems need to be solved. For a very long time, automotive assistance systems were operated in isolation in single cars and only with broad availability of mobile communication, first applications under the umbrella of "networked cars" emerged. At this time, connected car services were promised to drive improvements in driving efficiency, safety, comfort, etc., but unfortunately, they were mostly realized as manufacturer specific applications (e. g., BMW connect) with the hidden thought in mind to enable remote inspection of car use or situated in the multimedia/gaming domain (sharing of media, playing network games, or chatting between cars), which is also not really useful with regard to the original aim. Nowadays almost each newly sold car is connected to the Internet, and with it is the transition from formerly independently acting drivers and cars to connectedness with 'the rest of the planet' completed. (Even if the coverage of wireless vehicle communication technology on a global scale is still some years away, this is mainly a technological issue and actually will happen [15].) Complete interconnectedness of vehicles offers tremendous potential for services in the car centered around "social intelligence" or the ability of a system to understand and manage social behavior.

Until now, computers (and assistance systems) have been socially ignorant, i. e., they have not accounted for the fact that humans decisions are always socially inspired. But this will have to change in next-generation automotive information processing systems to include the essence of social intelligence in order to increase effectiveness and safety – time has come to offer social services to cars to allow them to interact in a similar way humans communicate and interact one with another. The car should, for example, relieve the driver by taking over tasks and accomplish them as efficiently as the human driver by applying sort of social intelligence. Socially behaving cars should create true value [3] for the road participants, and not just post the social status (feelings) of a driver or provide status information of the car (and collect "Like"s) as Facebook does...

Problems and Possible Solutions

Looking on global problems in road traffic, it is evident that traffic density and likelihood/duration of jams has considerably increased in the past decades. Together with it feel more and more drivers increased stress or anger from traffic, and a lot of people cancels or postpones planned trips due to anticipated high traffic. These problems cannot be solved by just adding another lane to the highway, build new roads, or push public transportation. A sustainable solution requires an holistic approach including new ways of traveling (platooning, car- and bike-sharing, active mobility, i. e. walking, bicycling, etc.), concerted coordination, and proactive management of traffic. This can be achieved, already today, by combining real time tracking data of vehicles, traffic flow sensing, and weather and event information, with analysis tools and simulation models to proactively control traffic and, thus, keep people moving more efficiently or safe. By applying concepts like incentivization it is likely that the behavior of cars/drivers can be (sustainably) changed.

Social acting vehicles could, for example, allow cars to automatically resolve conflicts in mass traffic, negotiate with each other, behave as a collective to optimize characteristics such as driving time or efficiency (e. g., waiting time in traffic jams or road charge to pay), to address the topic of environmental protection (reduced $CO2$ emission), to raise safety on the road by monitoring other cars' behavior in the vicinity, etc. More precisely, connected vehicles could issue warnings about potential dangers to other cars behind. Concerted deviation in the steering angle could, for instance, be used as an indicator of an obstruction on a otherwise straight road segment. If a vehicle at some distance ahead applies the brake hard, a system alert can be issued to all the cars behind to avoid (mass) rear-end collisions and a "slippery road surface" warning could be relayed to all drivers in a certain region if at some point, e. g., on a bridge ahead, several cars have applied their brake during the past time (recognized by a sensor in the power brake unit) and at the same time the CAN bus provide information that traction was lost. Depending on the outside temperature this might have been caused by road ice or oil slick.

More provocative, a social car could require a social environment (for example, intelligent roads with dynamically changing lanes; road signs adapting to the driver, etc.) and social cars should have real social capabilities, such as "learning" (car automatically recommends alternative routes if having learned that there is a traffic jam every workday in that region at a certain time; such behavior would in particular relevant for drivers using a rental car in an unknown area), "forgetting" (for example, vehicle moves more carefully after having been involved in an accident; however, the incident is forgotten after some time and avoids that the car is fearful and drive too slow in the long term), or "remembering" (a vehicle remembers from one winter to the next, that driving at or near the speed limit is not wise on temperatures below zero degrees or snow coverage on the road), etc. A presentation in the workshop would allow us to discuss even more potential application scenarios.

2. CONCLUSION

The "individual behavior enhancing" add-on of vehicles offers huge chances to improve driving efficiency, safety, etc. In particular, it is expected that sort of collective understanding of the traffic situation together with a concerted behavior modification of cars' should have the potential to enable improvements such as lowering global fuel consumption or $CO2$ emission, reducing traveling times, or increasing driving experience and pleasure. Achieved could this by a kind of "collective brain" gathering neural input from all the drivers in a common area of interest and featuring common decision making and negotiation on the route or lane taken by each individual driver within the collective...

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Ronald Schroeter	QUT	Australia
Monika Mitrevska	DFKI	Germany
Vedran Podobnik	University of Zagreb	Croatia
Rabindra Ratan	Michigan State University	United States
Helen Harris	Google US	United States
Bruce Walker	Georgia Tech Sonification Lab	United States
Melanie Lamara	BMW Research and Technology	Germany
Michael Doering	Robert Bosch GmbH, Corporate Research	Germany
Rod McCall	University of Luxembourg	Luxembourg
Ju-Hwan Lee	Korean German Institute of Technology	Korea, Republic Of
Jennifer Healey	Intel Labs	United States

Work in Progress

On the Influence of a Vehicle's Apparent Intelligence on Driving Behaviour and Consequences for Car UI Design

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ABSTRACT

We describe initial results form a car-simulator-based study. Specifically, we show a strong correlation between driver gazing behaviour and how intelligent they rated their car to be, indicating that human/car interactions are affected by the cognitive abilities ascribed to the vehicle by the driver.

Categories and Subject Descriptors

H.1.2 [**User/Machine systems**]: Information systems - Models and principles

General Terms

Design, Human Factors

1. INTRODUCTION

The present work in progress deals with how drivers perceive increasingly automated vehicles and how that affects their behaviour. More specifically, the simulator study, from which we present first results here, investigates whether the degree of *perceived* vehicle (or in-vehicle systems) intelligence correlates with changes in driving behaviour and expectations on human/vehicle interactions. Our overall hypothesis is that drivers will behave differently in a manner that affects driving style the more intelligent a vehicle *appears* to be. The latter can be influenced for instance by how interactive (communicating additional information to the user and accepting new commands) and/or autonomous (capable of carrying out certain tasks without driver interaction) the vehicle is. Here, we show that this appears to be the case. The present study is thus of interest to car UI designers since they may be able to influence this change in behaviour with their designs.

2. METHODS

2.1 Simulator, Environment, Task

It would go beyond the limits of this extended abstract to describe the experiment in detail. We therefore only describe aspects of our simulator-based study essential for the present results.

The simulator, equipped with an eye tracker, consisted of the front part of a real car (which the participants operated as they would a normal car) surrounded by a curved screen on which the environment is displayed. Participants were asked to drive through a road environment (see Fig. 1) towards goal positions as fast as possible while respecting traffic laws. They did so thrice. The first session served as a baseline in which traffic density was kept at a medium level, and only the upcoming junction number was displayed on the screen as an aid. In the subsequent sessions, participants experienced different traffic densities and had access to two types of navigation aids displayed heads-up on the screen: (1) Prior to each road junction, an arrow indicated which road to take and (2) additionally, a line of text justifying the choice was displayed (*e.g.* by claiming that the chosen road features less traffic). The overall purpose of the different mix of traffic densities and navigation aids described above was to provide a range of different driving experiences which may influence the apparent intelligence of the navigation aid.

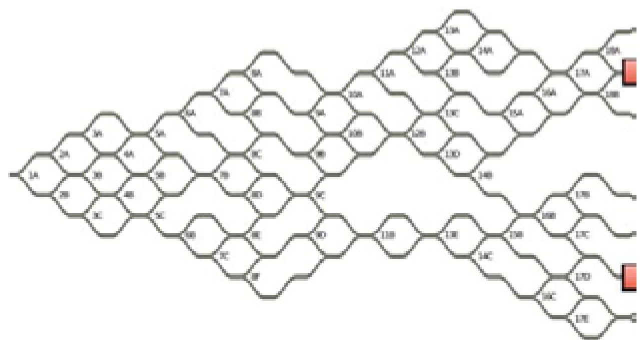

Figure 1: Environment map given to the participants. Far right boxes indicate both possible goals while the starting position is on the far left (before 1A). Junction numbers were always displayed in the simulator.

2.2 Participants and Procedure

Participants were asked to fill out a pre-questionnaire on background and existing expectations. They then performed the driving task as described above. To assess their cognitive load, participants also carried out a secondary task (counting short but clearly audible beeps). After each session, they were asked to fill out a questionnaire. Twenty-four participants (8 female, 16 male) completed the experiment while six participants did not, due to a failure to show up on time (1) or simulator sickness (5).

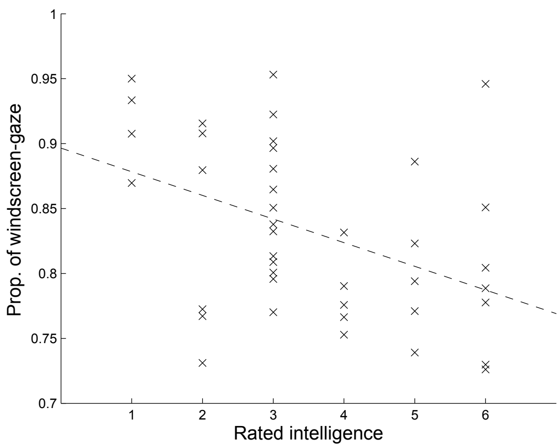

Figure 2: Scatterplot illustrating the inverse correlation between the proportion of total time drivers spend gazing through the windscreen and their own rating of the navigation aid's intelligence.

The questionnaires were used to identify match or mismatch of expectations and perceptions [2]. Each included a total of 17 statements, to be rated 0-6 on a Likert scale, targeting (a) apparent intelligence (b) performance of the driver and the system, (c) trust, (d) attitudes towards the system. Here, we only discuss first results pertaining to (a).

2.3 Data Collection and Analysis

Here, we considered three distinct variables. First, we measured driver behaviour through the proportion of the overall task duration that drivers spent gazing through the windscreen (here called *front gaze time* for brevity). We used an eye tracker designed to identify which particular region of interest the driver was looking at at any point in time (*e.g.* windscreen, mirrors, dashboard). Second, the performance on the secondary task is expressed as the participant's mean number of errors per occurring beep (a score of 0.1 would therefore indicate one error every 10 beeps) and is a measure of cognitive load, known to influence front gaze time [3]. Finally, the questionnaires assessed how intelligent participants judged their driving aids in the second and third trial. This therefore measures how intelligent drivers actually perceived the system to be rather than what may be expected given knowledge of the experimental design.

The fundamental question is whether or not the variables above are correlated. We expect in particular that change in behaviour is correlated with perceived intelligence (our core hypothesis). We therefore calculate Pearson's correlation coefficient r for each pair of variables while a T-test is used to determine the statistical significance of the correlation. Since some participants chose not to answer some of the relevant questions, forgot to carry out the secondary task or the eye tracker data was unavailable, the actual number of data points used here differ from the expected 48 (see the degrees of freedom ($n-2$) reported below).

3. RESULTS

We find, as hypothesised, that participants who rate intelligence higher had a significantly lower front gaze time ($r = -0.4255$, $p \approx 0.0005$, $df = 39$, see Fig. 2). Importantly, no correlation was found between the rated intelligence and the performance on the secondary task ($r = -0.0111$, $p > 0.9$, $df = 43$), indicating that cognitive load was not a decisive factor when assessing the intelligence of the navigation aids. The significant correlation between gaze time and rated intelligence is thus not just due the the effect cognitive load has on gaze. We also found (not discussed in detail here) that the most informative aid (arrows and text) tended to be rated more intelligent than arrows alone; the increase in gaze time in lower-rated conditions is thus not likely to result from the additional visual information. Finally, we found no significant correlation between the performance on the secondary task and front gaze time ($r = 0.1622$, $p \approx 0.3$, $df = 42$), indicating that the cognitive load here (including the secondary task) was not high enough to, by itself, significantly affect gaze time.

4. DISCUSSION

The results here show that changes in driving behaviour (gaze) correlate with the perceived intelligence of the navigation aids. This is notable since the more time is spent looking straight ahead, the less peripheral information is obtained (for instance from the rear view mirrors). As such, too much time spent looking ahead can be detrimental (as can too little) since it reduces the driver's ability to obtain a full picture of the traffic situation [3, 1]. The results here suggest that one way to influence driver gaze patterns is to manipulate how intelligent the vehicle appears to be through appropriate UI design.

As previously said, we also collected data pertaining to the driver's trust, detailed driving behaviour, performance and attitudes and the analysis thereof is ongoing. We next plan to address what factors influence perceived intelligence. This is not a trivial question since it is not necessarily the case that "better" or more "optimal" behaviour or even the automatic solving of more complicated tasks will directly influence this perception positively (in particular if the driver isn't even aware that this is happening).

5. ACKNOWLEDGMENTS

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Emergent properties of interaction and its implications for the design of electric vehicles

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ABSTRACT
Presented is a qualitative study that captures the experience of 16 first-time drivers of electric vehicles (EVs) taking part in a field study. The semi-structured interviews exposed the attributed functionality of the elements of the interface and their role in driving EVs. In particular, the importance of estimated range is highlighted. Findings show how drivers handle (learn) the range of the vehicle by exploring estimated range in terms of (a) the output (e.g., remaining range: 5 km) and (b) the dynamism of the same value (e.g., the slow/fast change) as well as (c) its combination with other information sources. The drivers' active search for immediate feedback, in addition to the accumulated/archival feedback, is highlighted. Presented is the current use of design elements and its implications for design.

Categories and Subject Descriptors
H.5 [**Information interface and presentation**]

Keywords
User experience, Human machine interaction, electric vehicle, information processing, automotive interface, decision making

1. INTRODUCTION
The ELectrical Vehicle Intelligent InfraStructure project (ELVIIS) is a cross industry project with the goal to ease the charging process of EVs by means of intelligent technology, see https://www.viktoria.se/projects/elviis. Two field-studies, in which drivers experienced EVs for one month each, investigated the value of driving EVs (Study 1) and the potential added value of information technology in EVs (Study 2). Reported is the first field study (Study 1), focusing on the driving experience and the usage of elements of the interface as information sources to the decision making process "driving EVs to destination X". The field study focused on 3 aspects of the driving experience, (a) the value of EVs (i.e., benefits/scarifies), (b) range anxiety, and (c) Human-machine-interaction, of which the latter (c) is of interest in this work-in-progress paper.

2. METHOD
2.1 Data collection
Collected are the self-reported experiences of EV drivers using Volvo C30 electric as their main vehicle of the household, for one month. In total, 16 in-depth interviews were performed after the completion of an EV trail period; 7 women and 9 men. The age ranged between 29 to 61 years old. Nine of the drivers had no experience of EV while 7 of them had limited experience (i.e., driven an EV less than 5 times). The follow-up session consisted of semi-structured interviews divided in two parts. Part 1: the drivers' perceptions and attitudes towards the EV. This included open-ended questions regarding value creation and critical incidents. Part 2: the drivers' interaction with the EV. This included open-ended questions regarding the usability and functionality of the interface using probes in the format of reaction cards. Each interview lasted for about 60 minutes. Part 2 is of interest in this extended abstract.

2.2 Analysis
All interviews were transcribed and qualitative assessed using the principles of grounded theory, i.e. "open coding" was performed [1,]. All interview material was analysed in relation to the conceptual model of value of Lapierre [2] to identify the value of EVs. Furthermore, all material was analysed from the perspective of distributed cognition [cf., 3] to identify the emergent properties of the interaction between the driver and the interface; thereby being able to differentiate the functionality, information provided and role of the interaction. The activity of interest was constrained by the decision: "I will/will not drive to destination A" and how that activity changed during the physical activity of driving the vehicle. Three levels of themes were identified in the process of grounded theory, "open-coding" [6] (cf. Section 3).

3. RESULTS AND ANALYSIS
Among the 16 drivers taking part in the study, *estimated range* was ranked as the most important information source (cf. Table 1). Other important sources were the *power meter* (N=4), *speedometer* (N=4), *battery status* (N=3), and *energy consumption* (N=1). Interestingly, each of the information sources had different function for each of the drivers (cf. Table 1). For instance, *estimated range* did not only provide information regarding the range of the vehicle (i.e., amount left) but also the success of charging, the effect of driving style, etc. Exploring the change (dynamism) of the value (i.e., the difference/fast/slow/sudden changes) allowed the drivers to use it as immediate feedback on, e.g., their driving style, increasing their understanding of how to drive EVs. This can be compared to the less used power meter (i.e., the intended immediate feedback provider). Moreover, using on the output of the value allowed the driver to use it as a warning (i.e., reference point), highlighting current progress. Interestingly, the battery status (0-5 filled boxes next to each other) intended to show progress was used to indicate current status.

Further analysis shows that a great majority of the drivers [D2, D4, D6, D8-D16] used two or more information sources in combination. This, in turn, expanded the functionality and added value of the sources (cf. Figure 1). In particular the following themes emerged: (a) increase the reliability/credibility; (b) lower uncertainty/ insecurity; or (c) to learn about the EV in terms of cause-effect relationships. Interestingly, as can be seen in figure 1, estimated range has most connections to other information sources

(N=4), followed by the battery charge status (N=3). It was most common to compare estimated range with the battery status (N=4). Also, the analysis suggests that the confirmation and ability to compare builds confidence of the drivers.

Table 1. Qualitative assessment of transcripts from the perspective of distributed cognition [9]

Source (N=number)	Level 1 analysis- condensed citation (D=driver)	Level 2 analysis – emergent functionality
	Information provided	*Role of activity*
Estimated range (N=16)	Information on current reach [D1-D11, D13-D14]	Feedback
	Information on the need for charging [D7, D16]	Feedback
	Information on driving style [D3, D11-D12, D16]	Feedback
	Information for competition with myself /others [D3, D9]	Reference point
	Information to be used for planning [D5, D13,D15]	Warning/ reference point
	Knowledge on the overall "health" of the EV [D10]	Warning
	I can see the saving potential [D3]	Reference point
	I know the current charging status [D9]	Warning
	Information on previous usage [D10]	Feedback
Power meter (N=4)	Information on current driving style [D7, D9, D13],	Feedback
	Information to understand the behaviour of the EV [D7],	Feedback
	to be used as a reference point [D11].	Reference point
Speedometer (N=4)	Information on speed [D2, D11, D14, D16]	Feedback reference point
Battery status (N=3)	Information on charge status [D1, D6, D15]	Feedback
Energy consumption (N=1)	Information current driving style [D12]	Feedback

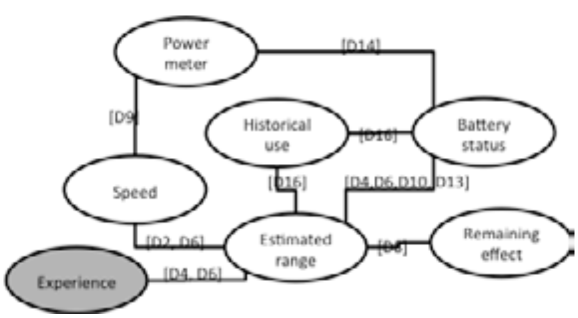

Figure 1. Physical (e.g., power meter) and non-physical information sources (e.g. experience) were combined to (a) add value, (b) increase understanding (c), or learn the effect of ones actions.

In addition, the results (level 3 analysis) indicate that the context of the activity (short/long trips, known/unknown destinations, first week/last week) was different between the different identified attributed functionality (cf. table 1). However, further investigations are needed.

4. DISCUSSION AND CONCLUSION

EVs provide a new set of information technologies and there is not yet a standard way of designing them [4]. This study highlights current use of interface elements and thereby gives suggestions for the design of such interfaces. For instance, it is noted that drivers compare and contrast the information provided to them to e.g. understand the effect of range and energy consumption (cf. 5-6), this feature may be utilised to a greater extent in the design of the interface by, e.g., providing proximity of typically combined information sources. Furthermore, the importance and multiple utilisation of "range estimation in km" highlight the drivers' current "locus of attention". Indeed, some of the participants did not notice warnings far away from the estimated range value. The focus towards this information source may be due to the ease of use, familiarity (similar information are present in gasoline vehicles), memorability of a specific value as compared to a scale, the continuous (visually) notable change in value, or the importance of the value due to the limited range of EVs. The findings indicate that the drivers consciously monitor this area (which should be explored by designers), and there are room for enhancing the design of the value in line with the attributed functionality (cf. Section 3), e.g., the use of colour to indicate progress to "empty".

5. ACKNOWLEDGMENTS

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A Model For Predicting the Visual Complexity of In-Vehicle Interfaces

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ABSTRACT
This paper describes the development of a model that can be used to estimate the visual complexity of in-vehicle graphical user interfaces (GUI) and to reduce the distraction of in-vehicle interfaces and thus improve the driving performance. The first version of this model was validated using a GUI that was designed for an interactive C2X application. Using the model, the visual complexity for different screens of the GUI was calculated. 22 participants performed a simple ticket reservation task with the GUI while performing a driving task. A significant correlation was found between the visual complexity and the time until action. Although this result indicates the potential of the developed model, the model has to be refined and further validated in future iterations.

Categories and Subject Descriptors
H.5.2. [**Information Interfaces and Presentation**]: User Interfaces -– *screen design, theory and methods*

General Terms
Design; Human Factors

Keywords
Visual Complexity, Graphical User Interfaces. Automotive UI

1. INTRODUCTION
When designing graphical user interfaces for in-vehicle use, a key consideration should be the impact of the interface on the driver. Currently, no ready-to use tool to predict this impact is available. Although it is expected that multiple factors play a role, this paper considers visual complexity as an important cause for driver distraction. When an interface is visually complex, we assume that the user needs more time to inspect the display and decide upon an action When the visual complexity of graphical interfaces can be predicted, design decisions can be made that decrease the impact on drivers' distraction and performance..This paper reports on the development of a model that predicts the visual complexity of individual, in-vehicle interface screens. Moreover, a first validation of the model is presented. Although the results are considered preliminary, they provide handles for a next iteration in which the model can be refined and validated further.

2. COMPLEXITY ESTIMATION MODEL
The complexity estimation model builds on the Annotated Complexity Estimation model (ACE) [1]. During the ACE procedure, interface designs are represented by tree structures. By valuing the different nodes of the tree a visual complexity can be predicted that takes into account element complexity and the complexity of the interface layout. The model that was created during this project uses a similar approach and determines an estimated complexity value for a single interface screen based on six parameters: (1) the number of nodes in the interface's tree structure, (2) the depth of the tree, (3) the overall contrast of the screen, (4) the sum of the complexities of the different geometries, (5) the sum of the complexities of the different words and (6) the number of characters present in the interface. The value for the overall contrast is calculated using the RMS contrast formula [2]. Geometry complexity is based on an empirical survey in which participants were asked to rate the different geometries present in the evaluated interface for complexity on a ten-point scale. A word frequency list [3] is used to determine the complexity of individual words. The complexity of words, as well as abbreviations, numbers and punctuation are also addressed by counting the amount of characters present in an interface screen. The values for all parameters are normalized between 0 and 1 and are weighed by 1 in this first version of the model. The sum of the parameters then results in an estimated visual complexity value of an individual interface screen.

3. VALIDATION
The complexity estimation model was validated using a graphical user interface (GUI) that was designed for an interactive Car2X application. The application allows drivers to reserve movie tickets for movies that are advertised on roadside displays.

3.1 THE GUI
The GUI supports ticket reservation through a step-by-step interaction dialogue. Social functions, like inviting friends, were also fitted in the step-by step structure. The different screens were designed for fast comprehensibility by using meaningful colors and limiting the amount of information presented to the bare essential. Since the interface was part of a multimodal HMI, the GUI aimed to support users in the speech interaction with the system. Actual touch interaction using the interface should be seen as the secondary modality that can be used in cases that speech in/output might not work satisfactory (e.g. in an environment with lots of environmental noise).

3.2 Method
For the validation, three screens of the GUI were selected. The screens allow users to (1) select a data and time, (2) select the

number of tickets and (3) select specific seats in the cinema (Figure 1). For all three screens three versions with different visual complexity were created (referred to as x.1, x.2 and x.3 where x stands for the selected GUI screen). The visual complexity of all nine versions was calculated using the developed model (Table 1).

Figure 1. A visually complex version of the screen that lets the user select seats (version 3.3).

All versions were made interactive using Adobe Flash and were combined in three ticket reservation interfaces. The sequences were presented to participants on a 7-inch touch display in a driving simulator. Participants were asked to perform three simple ticket reservation tasks using the three different interface sequences while performing a driving task. The ticket reservation task remained consistent over the three different reservation interfaces. The order of the conditions was counterbalanced among participants.

During this performance test, data concerning driving performance, gazing patterns and interaction patterns were collected. It is expected that a visually complex interface screen will negatively influence driving performance, increase the amount and duration of gazing at the display in the period between the initial presentations of individual screens until the first interaction. Moreover, the duration of this period is expected to be longer if a screen is visually more complex.

A total of 22 students of Saarland University took part in the experiment (mean age = 24.4, 12 male, 10 female). All participants owned a driver license. None of the participants was colorblind or had another condition that could negatively affect their performance during the experiment. In return for their participation, the participants received a fee of 8 euros.

3.3 Results

At the time of submission of this paper, only the durations of the screen initiation phases for every screen version had been analyzed (Table 1). Since it was likely that the relation between the durations and the complexity estimations would not be linear, a nonparametric procedure, Spearman's rho, was applied in order to calculate the correlation. Spearman's rho revealed a statistically significant correlation between the visual complexity values that were calculated with the model and the mean screen initiation phase duration ($r_s = .717$, $\rho < .05$) (Table 1).

Table 1. Mean initiation phase durations and calculated visual complexity per screen version

Version	N	Duration (ms)	Complexity
1.1	22	7869	3.388
1.2	22	11873	2.030
1.3	22	13135	2.648
2.1	22	3710	1.270
2.2	22	3366	1.482
2.3	20	7228	1.589
3.1	22	10378	1.866
3.2	22	4830	0.900
3.3	22	11421	2.850

4. DISCUSSION AND FUTURE WORK

Although these first results are promising and give an indication of the potential of the complexity estimation model, the model should be further refined. By experimenting with the weights for the different parameters that constitute the estimated complexity value, the effect of the different parameters should be determined. Especially the parameters for word complexity and character count might have a substantial influence on the complexity in comparison to the other parameters.

Looking at the qualitative observations by the experimenter during the experiment, there are indications that the contrast of the different elements should have had a more prominent role in the model's equation. Looking at Table 1 the high mean durations for version 1.2 and 3.1 can be partially explained due to the lack of contrast of the target elements. According to the observations and the comments, participants had trouble recognizing some of the elements in these screens as interactive elements due to poor color contrast and transparency.

Further analysis of the driving performance and gazing patterns that were measured during this experiment will provide more insight in the trustworthiness of this correlation. The collected dataset in combination with observations and comments by participants has provided valuable information for the start of a next iteration in which the model can be adjusted and evaluated. The general effect of any adjustments could be quickly assessed using the dataset that was collected during the experiment for this project. In future validations, a larger sample and more experiment conditions should be tested in order to assess the robustness of the model.

5. ACKNOWLEDGMENTS

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Detection of Drivers' Incidental and Integral Affect Using Physiological Measures

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ABSTRACT
This paper discusses the initial findings of an on-going study to determine the affective state of the driver using physiological measures. Incidental (writing past experiences) and integral (hazard events while driving) anger were induced and heart rate was measured throughout the simulated driving experiment. This exploratory study shows the possibility that average heart rate (i.e., beats per minute) can be used to detect both incidental and integral anger, respectively. Future research is planned to determine if the patterns of data fusion can be used by in-vehicle systems to identify specific emotions of the driver and offer counteractive feedback to reduce potential driving errors.

Categories and Subject Descriptors
J.4 **[Computer Application]**: Social and Behavioral Sciences–Psychology

General Terms
Measurement, Design, Human Factors

Keywords
Affect, Driving Simulation, Emotion, Physiological Measurement

1. INTRODUCTION
It is understood that a driver experiences an array of emotions while driving; an example is that angry driving and road rage can decrease driving performance most seriously [e.g., 2, 8]. Recent literature [6] confirms that angry drivers made more driving errors than fearful drivers, which demonstrates that emotions of the same negative valence (i.e., anger and fear) could result in different driving performance. Such emotions (e.g., anger) can be experienced incidentally or integrally [1], meaning that the source of the emotion is either unrelated (e.g., fighting before driving) or related to the primary task (e.g., tailgating while driving).

Researchers have sought to detect emotions for drivers using speech detection or facial detection [e.g., 7, 10]. However, physiological measures have typically been used to monitor drivers' mental workload [e.g., 9], but rarely used to detect drivers' emotions. This study is part of a larger project to develop a real-time emotion detection and regulation system for various drivers. Ultimately, we aim to implement such a system based on data fusion (i.e., integration of autonomic measures, startle response magnitude, brain states, and behavioral measures). The current phase explored the idea that physiological measures (e.g., heart rate, respiration, etc.) could be used to determine the driver's current emotional state and potentially differentiate between incidental and integral affect. The present paper concentrates on the result of heart rate data with induced anger. The results of this study are expected to help develop an in-vehicle system to determine the driver's emotional state and provide multimodal feedback to reduce potential driving errors associated with such affect.

2. METHOD
2.1 Participants
Ten students, 6 females and 4 males, participated in this study for partial credit in their psychology course. Students ranged between 19 and 39 years of age (*median years of age* = 21, *SD* = 6) and had at least 3 years of driving experience (*median years driving* = 6, *SD* = 6) with a valid driver's license.

2.2 Apparatuses
The BioPac Student Lab *PRO*® electrocardiogram (ECG) hardware was used to obtain average heart rate (i.e., beats per minute (BPM)) before and during simulated driving. A modified 3-lead ECG sensor set-up was used to obtain the average BPM. Sensors were placed on the participant's chest as opposed to the limbs to help reduce output noise due to physical movement. We used a quarter cab version of National Advanced Driving Simulator's MiniSim version 1.8.3.3[1].

2.3 Procedure
After completing a consent form, participants were screened for simulation sickness. If the participant was prone to simulation sickness, the experiment ended and the participant was debriefed. If the participant was not prone to simulation sickness, they were asked to rate their affective state using a seven-point Likert scale [5]. The ECG sensors were then placed on the participant and they remained still, for 5 minutes to obtain their average resting BPM (e.g., baseline BPM). Following baseline BPM measurements, incidental affect induction took place. To induce anger, participants were asked to write about a past experience, that they could vividly revisit, in which they became angry. Prior to writing, the participant read two example paragraphs, which described two situations where a person became angry, including a driving-related example [6]. After writing, the participant rated their current affective states and completed a general driving and risk perception questionnaire [e.g., 3]. Next, the participant drove approximately 12 minutes in the driving simulator, which included 9 hazard events (e.g., car swerving into their lane, deer in the road, pedestrian running into the street). After driving the participants rated their affective states for the third time and completed an electronic version of the NASA-TLX [4]. After completing a demographics survey, they were debriefed.

[1] See (http://www.nads-sc.uiowa.edu/minisim/) for the detailed specification. Retrieved September 25, 2013.

3. RESULTS

3.1 Self-Rating Data

The average score for each of the three anger ratings is shown in Figure 1. All ten participants' data were used for self-rating analysis; however, three participants' data were excluded from the physiological data analysis due to extreme noise within the data. A paired-samples t-test showed significant differences between the three anger ratings. The anger rating after induction (M = 3.20, SD = 1.23) was significantly higher than before induction (M = 1.10, SD = 0.32), $t(9) = -5.55$, $p < .001$. The anger rating after the study (i.e., following driving) (M = 2.30, SD = 1.49) was also significantly higher than before induction (M = 1.10, SD = 0.32), $t(9) = -2.57$, $p < .05$. Overall, anger level increased after induction and decreased while driving; however, both anger ratings after induction and at the end of the study were significantly higher than before induction.

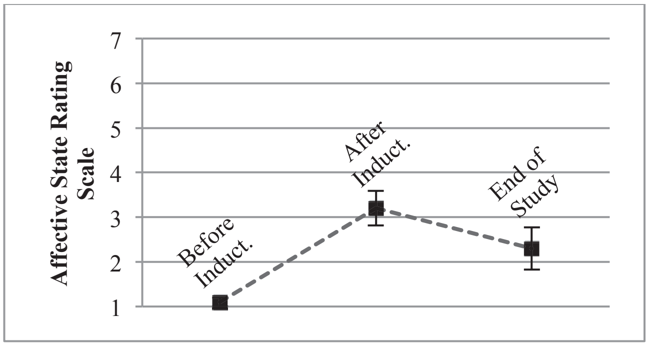

Figure 1. Average anger-rating scores across rating timings. Error bars indicate standard error of the mean.

3.2 Physiological Data

Figure 2 shows the average heart rate (i.e., BPM) during the following events: baseline, reading, writing, driving-only, hazards one through nine. Reading and writing were assumed to induce incidental anger and hazards while driving were assumed to induce integral anger. Average heart rate increased after incidental affect induction as compared to the baseline. Moreover, all but one hazard event resulted in an increased heart rate as compared to both baseline and driving-only measurements. Specifically, the hazard 2 (motorbike) (M = 76.85, SD = 7.50) showed significantly higher BPM than the driving only (M = 71.10, SD = 7.46) $t(9) = -2.77$, $p < .05$. However, other than that, none of the heart rate differences led to the conventionally significant level, potentially attributed to a small sample size. A decrease in heart was observed during the driving-only part of the experiment. This decrease is speculated to be a result of the participant's comfort with driving in the simulator, as writing about a past angry experience was a novel activity in comparison to previously driving in the simulator. This past simulator experience may have made the participant feel more comfortable than the novelty of writing and thus their heart rate decreased while driving-only.

4. CONCLUSION & FUTURE WORKS

Overall data patterns indicate that physiological measurement (i.e., average heart rate measured in BPM) could be used to identify the affective state, anger, compared to the baseline. Further, it demonstrates the benefits of physiological measurement in detection of both incidental and integral affect, whereas the self-rating can be used to identify only incidental affect.

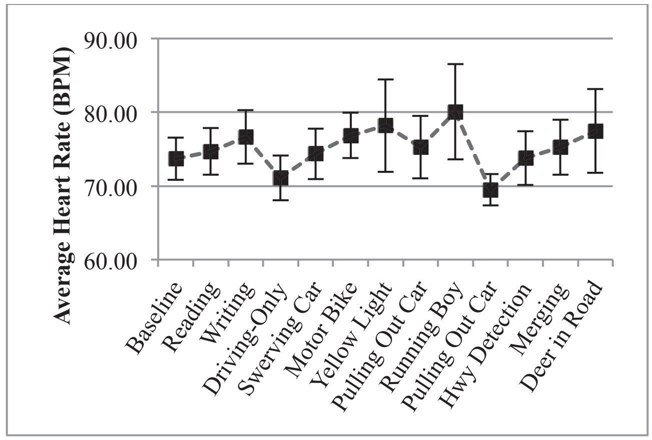

Figure 2. Average heart rate (BPM) at each experimental event. Error bars indicate standard error of the mean.

More detailed pattern recognition techniques will be applied to create an algorithm with which our in-vehicle assistive technology can identify the various affective states (e.g., anxiety, depression, happiness, in addition to anger) of the driver and offer intervention strategies to potentially enhance driver's experiences and reduce driving errors. In addition to the analysis of the accompanied respiration data, planned research includes the combination of the use of multiple measures: facial detection, body posture, brainwaves, etc.

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Influences of Socio-Demographic Factors, Personality Traits and Car Usage on Cooperative Guidance and Control

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ABSTRACT
This article investigates the relations between different user groups and the perception of a cooperative approach of guidance and control of highly automated vehicles. Results of a user study regarding the influences of user characteristics, such as personality traits, gender, education, driving experience, and driving habits, on preferences for cooperative guidance and control are reported and discussed.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Haptic I/O, User-centered design*; H.1.2 [**Models and Principals**]: User/Machine Systems—*Human factors*

General Terms
Human Factors, Experimentation

Keywords
User diversity, man-machine systems, cooperative guidance and control, highly automated, socio-demographic factors, personality traits, car usage, driving experience

1. INTRODUCTION
In the last decades mobility gained an enormous impact on everyday life. Distances regarding commuting, business trips, and private obligations are continuously increasing. At the same time the user group of individual traffic is becoming more and more heterogeneous. A user study was conducted using a simulator to reveal the different expectations on cooperative guidance and control due to gender, education, personality traits, such as communicativeness or openness, and driving experience and habits.

2. STUDY
A user study was conducted in a driving simulator with a horizontal FOV of about 80 degrees and an active sidestick as control device. The driving scene was a section of a three-lane highway with fellow cars. The **cooperative guidance and control** concept [1, 3, 5] was the H-mode [3] inspired by the design metaphor of horse and rider [2]. H-mode is a holistic haptic-multimodal approach to cooperative guidance and control, where the control is dynamically distributed between driver and automation [3, 4].

In total 20 people $(10f, 10m)$ participated in two test series. **Participants** were aged between 19 and 34 years with an average age of 24.5 years (SD=3.8, M_f=24.4, M_m=24.5) and held a driving license. The two-hour **study** included a preliminary questionnaire regarding socio-demographic data, personality traits, and car usage. The second part particularly aimed at user participation in the design process [4]. The last part was a two-stage evaluation with a 10-minute training in between. The participants rated items, such as perceived safety, on a 7-point semantic differential scale. The results of the preliminary questionnaire and the evaluation after the last simulator drive are most valuable for investigating correlations with user groups since participants gained high familiarity with the system. In the following the correlations are reported and discussed.

3. RESULTS
The data analysis revealed important correlations between socio-demographic data, personality traits, car usage, and the perception of the cooperative approach of guidance and control. As the number of participants was limited to 20, the results might not be representative for the overall population but provide essential indications for further studies. The correlations were quantified using Spearman's correlation coefficient, r_s, and the t-test.

3.1 Socio-Demographic Factors
The study revealed numerous correlations between **gender** and the perception of the cooperative approach of guidance and control. Men answered the general item of the overall perception of the approach more positive (t=1.857, p=0.08). Women rated higher on the haptic option of fluid transition between automation levels by gripping strength (t=−1.958, p=0.066). Due to small **age** variance no correlations were found whereas several effects regarding education were revealed. **Education** measured by the highest educational achievement correlated significantly with perceived safety (r_s=0.461, p=0.041), perceived ease of driving, and perceived controllability of the vehicle especially due to automation level transitions (r_{s_e}=0.475, p=0.034; r_{s_c}=0.530, p=0.016), although there were no correlations for subjectively perceived learnability and ease of system use.

3.2 Personality Traits

The personality traits were rated on a 5-point Likert scale. *Communicativeness* and *openness* – defined as average of the items *general openness for new experiences* and the highly significantly correlating item *open-mindedness for new technical developments* (r_s=0.728, p=0.000) – showed the most interesting influences on the evaluation of the approach of cooperative guidance and control. **Communicativeness** includes not only communication skills, but also enjoyment of communication, which is basic for cooperation. Someone might expect that especially highly communicative people enjoy cooperative approaches but communicativeness also implies a higher need for communication. In general, communicativeness and estimation of the cooperative approach tend to correlate negatively including some significant cases, such as subjective contentment while driving with H-mode (r_s=−0.456, p=0.043) and especially the perceived safety while driving temporarily fully automated (r_s=−0.445, p=0.049). The reason might be the comparatively low interaction between driver and system in this automation level. Another explanation might be the perceived imbalance of control distribution in favor of the system, which is supported by the negative correlation between communicativeness and how comfortable participants felt with the control distribution (r_s=−0.412, p=0.071). Other significantly negative correlations were found for mode awareness (r_s=−0.525, p=0.017), transitions using buttons on the interaction screen (r_s=−0.454, p=0.044), and the overall understandability of the interaction screen (r_s=−0.459, p=0.042), which is in line with the above mentioned explanation of higher needs and expectations regarding communication. Though not significantly correlating with the general estimation of H-mode, **openness** correlates significantly negative with the comfortableness of participants while using the highly cooperative automation level of highly automated driving (r_s=−0.452, p=0.045). It also correlates negatively with the perceived safety (r_s=−0.403, p=0.078). In future work it is interesting to investigate the relations between automation level perception, openness, and additionally participants' general need for security as highly automated driving is in general perceived to be the safest level ($M_{assisted}$=4.3, $M_{highaut}$=6.1, $M_{tempaut}$=5.7).

3.3 Car Usage

Car usage includes the aspects *driving experience* and *driving habits*. **Driving experience** is deduced from the *average mileage per year* and the highly significantly correlating *driving frequency* (r_s=0.655, p=0.001). The strongest relation between driving experience and the perception of the cooperative approach of guidance and control was found in how much easier driving was experienced by less driving people in the cooperative approach than without assistance in the simulator (r_s=−0.468, p=0.038). The perceived quality of cooperation between participant and system correlated negatively with driving experience (r_s=−0.458, p=0.042). For all levels of automation, the same tendency can be found. Participants with low driving experience reported the biggest benefits including feeling pleasant, perceived safety and control distribution. The weakest correlations were found for assisted driving, while highly automated and temporarily fully automated driving had strong negative correlations with driving experience. Driving experience correlated significantly negative in the automation level highly automated with perceived safety (r_s=−0.451, p=0.046) and contentment of the participants with the control distribution (r_s=−0.455, p=0.044). Besides driving experience **driving habits** revealed important correlations. People who *enjoy driving across the country* tend to devalue the utility of the system (r_s=−0.403, p=0.078) whereas people who mainly *drive from A to B* were more positive about the quality of cooperation (r_s=0.424, p=0.063). People using the car mainly for *routine drives*, which highly correlates with driving experience (r_s=0.592, p=0.006), rated the predictability of the system significantly low (r_s=−0.448, p=0.047). Any small deviation from their routine might be perceived exaggerated. For the interaction screen a significantly negative correlation was found (r_s=−0.535, p=0.015). Not surprisingly, people stating to *enjoy the activity of driving* tended to rate comparatively high on only assisted driving (r_s=0.402, p=0.079) and had a significantly good mode awareness (r_s=0.545, p=0.013), which is contrary to the influence of communicativeness (see above). The less people *drive alone* the more they enjoyed the control distribution of the very cooperative automation level of highly automated driving (r_s=−0.503, p=0.024). In future work it should be investigated if this was a result of sociable character in general.

4. CONCLUSION

The study revealed numerous important correlations between aspects of cooperative guidance and user characteristics, especially regarding the socio-demographic factors gender and education, the personality traits communicativeness and openness, and the car usage aspects driving experience and habits. These results indicate a need for a flexible, versatile driving assistance that easily adapts to the expectations of different user groups. Future studies need to be performed in order to investigate these influences with a larger number of participants to deduce specific design recommendations.

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Driving Simulator Sickness Screening: Efficient and Effective New Protocol

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ABSTRACT
Driving simulators allow researchers to study situations that would otherwise be difficult or impossible to investigate. Simulator sickness can negatively affect these studies, make participants uncomfortable or ill, and waste the time of both participants and researchers. A new, faster, simulator sickness screening protocol has been developed, based on prior protocols. We describe an ongoing longitudinal quantitative assessment using an electronic version of the screening protocol to verify our initial experience with a paper version of high accuracy in excluding participants who would otherwise have to drop out of a driving study due to simulator sickness.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces And Presentation (e.g., HCI)**]: User Interfaces –graphical user interfaces (GUI), interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design; I.6.7 [**Simulation and Modeling**]: Simulation Support Systems

General Terms
Design, Experimentation, Human Factors.

Keywords
Simulator Sickness Screening, Driving.

1. INTRODUCTION

1.1 Simulator Sickness
Simulator sickness (SS) occurs for some people when they use a simulator. Symptoms of SS are similar to those of motion sickness (MS), and can include disorientation, dizziness, headache, dry mouth, and even drowsiness, vomiting, and nausea. Fortunately, SS tends to occur less frequently than MS, and with less severe physical and mental symptoms [1, 2, 3]. Nevertheless, SS can still have negative effects on an experiment, and confound data through reductions in psychomotor control and participant dropout [2]. And, of course, due to the potential negative effects of SS on participants it is vital to try to decrease the frequency and severity of symptoms, so as not to harm participants [1].

1.2 Screening for Simulator Sickness
Several attributes of driving scenarios (e.g., curves, steady braking, intersections, time driving, and speed of the simulated vehicle) and physical simulator or environment-based factors (e.g., room temperature) have been found to impact SS [1,5,6,7,8,9]. While researchers have attempted to modify these factors to address SS, others have attempted measuring SS (and then dealing with it later during data analysis) to tackle the issue. To this end multiple SS measurement scales have been developed over the years. Some of the original SS measurement scales were based on measurements of purely *motion*-related symptoms; examples include the Pensacola Diagnostic Index (PDI) and the Pensacola Motion Sickness Questionnaire (MSQ) [10,11]. Problems with these measurements for driving simulator use included their reliance on a single score of determining SS, and not being designed specifically for SS. This led researchers to create new multidimensional scales such as the SS questionnaire (SSQ), and MS assessment questionnaire (MSAQ) [3,11].

Unfortunately, addressing environmental factors and measuring any residual SS was not sufficient. Researchers determined they needed to screen individuals before participating in a driving study. However, by giving pre-screening surveys based on previous SS or MS, researchers screened out some who would not get SS in the study. Other researchers saw the possibility of using an SS survey, plus the completion of a scenario in the simulator, to screen for SS [1,7]. For that reason, Brooks et al. adapted the MSAQ and reported more than 90% accuracy in their screening protocol [1].

The present study is an attempt to measure the effectiveness of the new Georgia Tech SS screening protocol. The procedure and supporting software tools, were developed for the Georgia Tech School of Psychology's mid-fidelity, fixed base driving simulator, and is discussed in greater technical detail in [4]. The ongoing research aims to determine how well the screening protocol identifies participants who may experience SS during a study, before they begin. This is done to avoid harming subjects through experiencing strong reactions of SS after longer exposure, and in order to save time of the researchers and participants. The earlier version of the SS screening method worked very well after its development, but the current electronic version was created to speed up the process and to allow for ease of quantitative longitudinal evaluation of its effectiveness.

2. METHOD

2.1 Participants
The sample for this research is a combination of participants from separate driving research studies in a large research university in the southeastern United States. Participants are required to have a valid driver's license and normal or corrected-to-normal vision.

2.2 Apparatus

2.2.1 Driving Simulator
The driving simulator used in this study is a quarter-cab National Advanced Driving Simulator (NADS) MiniSim. The simulator's visuals are displayed on three 42" plasma monitors and an LCD

screen for the instrument panel. The simulator conveys sound through a 2.1 audio system and participants use an adjustable steering wheel, gas and brake pedals, and gear shifter for input.

2.2.2 Screening Protocol

The current screening protocol including the apparatus and the procedure will be briefly described below, however for more detail see Gable and Walker [4]. The GT SS screening survey used here is a modified version of the version of MSAQ used in Brooks et al. [1]. In this version, participants use a touch screen unit fixed in the simulator to answer 17 questions about their current state of feeling. The survey uses a scale from 0 to 10 where 0 is "not at all" and 10 is "severely" regarding the dimensions of: sick to stomach, faint-like, annoyed/irritated, sweaty, queasy, lightheaded, drowsy, clammy/cold sweat, disoriented, tired/fatigued, nauseated, hot/warm, dizzy, like I am spinning, if I may vomit, uneasy, and floating. They then complete a short (2 minute) drive through a purpose-built scenario using the NADS scenario development tool. The driving scenario's brevity keeps the acclimation drive short, while still introducing drivers to maneuvers that may trigger feelings of SS. Finally, drivers complete the survey a second time, after the drive.

The computer then calculates any changes in physical feeling between the two drives, and recommends whether the driver should continue with the study or not. If at any time during the acclimation drive (or later in the study) participants report any feelings of sickness, the simulation is stopped.

2.3 Procedure

Over the course of a number of months all participants who partake in simulator studies using the School of Psychology simulator have gone, and will continue to go, through this new electronic version of the protocol before the start of the experiment. When a participant is removed from a study due to the screening or partway through a study due to SS these data are recorded in the database. At the end of the study period all of the screening files output by the program will be analyzed to quantitatively assess the effectiveness of this screening technique.

3. CURRENT AND EXPECTED RESULTS

Since this screening process was adapted in part from Brooks et al. who found accuracy of above 90% in their screening process it is to be expected that this screening should show a similar validity [1]. Accordingly it is predicted that only 10% or less of participants that make it through the protocol without being recommended to stop will exhibit SS symptoms and have to stop the study part way through. Although not enough screenings were done with the paper version of the screening for a statistical analysis of the magnitude desired we did not have any participants drop out of studies due to simulator sickness post screening.

It is our expectation that the current, more formal, and quantitative evaluation will echo our initial and anecdotal findings. It should also be said that, even though screening times and ease of assessment are not reported in other studies, this new protocol is expected to be faster and more efficient than other screenings due to our use of in-vehicle assessment, a computerized survey using a touchscreen interface, automated scoring, integrated data archiving for longitudinal evaluation, and the short (2 min) acclimation driving scenario.

4. DISCUSSION

The newly developed GT simulator sickness protocol is already showing great promise. If, after this more formal evaluation, the screening protocol is indeed found to be as effective and efficient as it seems, it will enhance the driving research performed at Georgia Tech. Of course, our intentions in developing such a tool is to share it widely with other MiniSim users, and help adapt it for use in other simulators. While the current investigation is focused on young populations, research has found relationships between age and prevalence of SS [1,8]. Thus, we plan to systematically expand the range of participants screened, including older adults and those who have various special challenges (e.g., drivers with traumatic brain injury, low vision).

5. ACKNOWLEDGMENTS

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Taking Reality for a Drive in the Lab: The Makeup of a Mockup for Automotive HMI Research

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ABSTRACT
In this paper we introduce our ongoing efforts constructing a hardware simulator car mockup for automotive HMI research. We achieved a solution suitable to conduct controlled experiments resembling the ergonomic properties of a real car while still allowing reasonable flexibility for a quick explorative prototyping of interfaces. In contrast to existing solutions in a comparable price range our mockup not only seats a driver plus front seat passenger but also three rear seat passengers. We show how the combination of a modular construction system with car repair parts and off-the-shelf consumer electronics allowed us to keep the cost below EUR 10.000.

Author Keywords
Car, Mockup, Simulator, DIY

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces – Benchmarking, Evaluation/methodology, Prototyping

INTRODUCTION
Car simulators have shown to be a valuable tool in automotive HMI research with a wide range of possible solutions [3]. In terms of the car representation itself, the highest level of realism is achieved by using real cars, half cars, or their cockpits that can be referred to as high fidelity driving simulation environments (see e.g., [2]). These settings can suffer from high costs and a reduced flexibility for prototyping. Installing, for example, a prototype in a central console position in a real car dashboard requires skills and time (e.g., wiring, mounting) and may be hard to revert. Identifying a gap between high and low fidelity car mockups, we decided to go into a new direction creating a medium fidelity solution.

MOCKUP
Our approach on creating a medium fidelity car mockup for automotive user interface research is based on the combination of three types of components: (i) a building kit system for industrial applications; allowing for flexible adaption of the spatial and ergonomic conditions as well as quick adaption in prototyping efforts (ii) off-the-shelf consumer electronics, and (iii) car spare parts, allowing us to achieve the look and feel of a car and maintain a reasonable level of fidelity and immersion while keeping the costs low. As shown in figure 1 we use the mockup in front of a projection, utilizing different kinds of simulation depending on the experimental setup.

Figure 1. The car mockup, situated in a simulation environment

Mockup Form Factor and Dimensions
We chose to follow the basic shape as well as the dimensions of a very common middle-class car, namely a 2009 Volkswagen Golf. This allowed us to achieve realistic ergonomics with a reasonable effort by maintaining the main dimensions of this real world blueprint, e.g., point-to-point clearances.

Mockup Structure and Chassis
The chassis is custom built using the ITEM building kit system for industrial applications[1]. Using a industrial grade building kit enabled us to quickly build robust structures while maintaining a high level of flexibility, as all conjunctions are kept adjustable and every part of the mockup can be replaced at all time. Installing and uninstalling a screen, for example, is thus possible at nearly all locations in the mockup without leaving a permanent damage.

Seats
As the seating position is crucial for any considerations of ergonomics in the car we selected a pair of spare seats from

[1] http://www.item24us.com

a van. These seats offer an increased range of adjustment compared to more common types of seats. e.g., from compact cars. This was essential as it allowed us to go for a simpler, non adjustable design of the steering wheel mount while still maintaining a reasonable degree of adjustment of the seating position in respect to steering wheel and pedals. Moreover, the seats' extent flexibility has also shown to be very valuable when incorporating technology that to a certain extend needs to be coherent with the position of a study participant's head and eyes, e.g., head up displays or eye trackers.

Primary Controls
The primary controls are based on the ClubSport Wheelbase from Fanatec[2] that features a wheel rim that can be quick-released from its base and exchanged with rims of different size and style. This mounting solution allowed us to not only use the different rims provided by the vendor, but moreover adapt wheels from real cars for their usage with our mockup. Custom modifications of the system enabled us to design and implement tailored prototypes of interfaces on dedicated wheels using prototyping platforms (e.g., Arduino[3]). At the same time the wheelbase stays fully functional and allows us to take those prototypical wheels for a drive with off-the-shelf driving simulation software and even driving games without the need for any additional fitting.

Dashboard
To experiment with various dashboard designs we utilize a USB-driven screen combined with custom in-house software that allows us to wire up the dashboard to a growing collection of available simulation software as well as interface prototypes under development. In order to compare novel dashboard designs with state-of-the-art dashboards the display can easily be replaced with a dashboard from a current car we retrofitted by replacing the manufacturer dependent electronics with an Ethernet capable Arduino.

Central Console
Our design of a central console followed a similar approach: The horizontal clearance of the skeleton we built for the central control is based on standard size for car audio head units as specified in ISO 7736 [1]. This allows us to quickly install various head units and other hardware from OEMs (original equipment manufacturers), aftermarket solutions, as well as custom built prototypes, e.g., a panel with controls for the color of the interior light.

Rear Seat
Our research interests around social aspects in the car asked for the incorporation of a rear seat area into our mockup. Similarly to our considerations for the front seat area, we selected seats for the back of our mockup that feature multi-axial adjustability of the back rest as well as the individual seat. This adds flexibility for the positioning of interface elements in respect to the passengers. The front and back seat area are built upon two separate base units on casters. Thus the whole rear part can be detached from the front of the car whenever suitable, allowing for easier access during modifications.

[2]http://eu.fanatec.com/
[3]http://www.arduino.cc.

Basic electric facilities
While the focus of this mockup lies on its physical characteristics as a platform for prototyping, a well-balanced level of basic electric equipment is still sensible as some components and features come in handy in many use cases. We chose to integrate a linear power supply providing 13.8V that fits the current supply of most modern cars and thus allows for the straight forward integration of most automotive electronic devices and accessories. We installed interior lighting in both front and rear seat area (see figure 1) using RGB LED strips. Custom controls in the central console are used to adapt color and brightness to the necessities of a particular system or interface studied in the mockup (e.g., different screen configurations or face-tracking ask for certain illumination of the modalities respective a study participant's face.)

Study Equipment
The mockup provides mounting options and all the wiring necessary to quickly (un-)mount optional study hardware. As an example we installed wiring concealed inside the mockup's structure for the installation of an eyetracker. In a similar fashion we installed wiring for optional cameras and microphones in multiple locations.

Odds and Ends
The building kit system used allowed us to quickly add small details and widgets present in most cars, e.g., a rear view mirror or handle bars. While the rear-view mirror is not functional as of yet, i.e. there is no simulator content shown in the mirror, it is valuable considering the contiguity between front and rear seat area. While some of those small parts might not seem relevant at first glance, we found that they add to the immersion achieved by the mockup. The described components allowed us to fulfill the presented requirements while sticking to the target costs of approximately EUR 10,000. The main costs were the parts of the building kit system (EUR 5,500) as well as the required special tools (EUR 800). Second-hand car components, i.e. seats, steering wheels, rear-view mirror, etc. added EUR 500, various material for outfitting the interior EUR 600. The used consumer electronics (i.e. steering wheel base, screens, etc.) caused costs of EUR 2,000.

CONCLUSION
We present a flexible and low-cost car mockup combining the benefits of adjustable hardware elements, standard electronic equipment, as well used car parts. It aims at filling the gap between high-fidelity car simulation environments based on real cars often lacking flexibility and low-fidelity simulators providing a low degree of ergonomic reality.

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Personalized situation-adaptive User Interaction in the Car

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ABSTRACT

The complexity of the interaction with DAS and IVIS increases due to the steadily rising number of functions in the vehicle which can result in the problem of driver distraction. A solution is to provide a personalized and situation-adaptive support. This means offering an easy and fast way to access the needed functionality. The existing approaches provide solutions only for specific functions in the field of IVIS. Our approach is based on an overall architecture, which includes DAS and IVIS and which provides a prioritization of support possibilities depending on the situation. The needs of the driver are identified depending on the situation and a support in form of the adaptation of the function set in the menu or executing preconfigured actions with or without confirmation of the driver is provided. Both reduce the complexity of the interaction by minimizing the number of operation steps.

Categories and Subject Descriptors

H.1.2 [**User/Machine Systems**]: Human factors

General Terms

Architecture, Human Factors

Keywords

distraction, personalization, situation awareness, adaption, user interaction

1. INTRODUCTION

The rising number of functions in the vehicle within both driver assistance systems (DAS) and in-vehicle information systems (IVIS) results in an increasing complexity of the interaction which can lead to driver distraction. A study from the German Federal Highway Research Institute (BASt) on the topic of distraction due to non-driving tasks points out this problem. For instance 12% of the accidents caused by distraction in the vehicle are related to entertainment systems. And 92% of these accidents happened because the driver was operating the system [5]. The challenge for the human-machine interaction (HMI) development is to support the driver by providing an easy way to operate and use the functions of such a complex system. This means having a higher user acceptance and less distraction, e.g. by reducing the number of operation steps. At present, several approaches provide solutions for specific functions in the field of IVIS. But there is no solution, which addresses an overall architecture, where both DAS and IVIS are integrated, and which provides a prioritization of support possibilities depending on user needs. To achieve this, we propose an approach which is based on an overall architecture and provides prioritization to realize a fast access of functions.

2. RELATED WORK

Within the project AIDE, wherein the goal was to develop technologies for integration of ADAS, IVIS and nomadic devices into the driving environment, an overall system with an Interaction and Communication Assistant (ICA) and a Driver-Vehicle-Environment (DVE) module was developed. The DVE module gets sensor information about driver, vehicle and environment, deduces knowledge and provides the knowledge to applications and the ICA. The ICA manages and adapts the driver system interaction based on rules and dependent on the knowledge provided by the DVE module [1]. A DVE module for situation recognition similar to the one from AIDE was developed in the smart car project to provide context-awareness in the vehicle. It uses a layered architecture to deduce context information from sensor values and then concludes situations using an ontology [8].
On this basis, the needs of the driver can be identified. Many approaches that support the driver within a specific task like [4] and [7] primarily observe the user behavior concerning the use of functions relating to a situation to identify the needs and preferences in the present and future. In [2] a model for situation recognition similar to the one in the smart car project is used, which also uses knowledge about the past and the current situation and in [3] only a user model and a data base for personalization is used.
If the driver needs are identified, there are several strategies to provide an easy and comfortable access to functions. One approach is to use adaptive user interfaces (AUIs) which adapt menus or the set of functions according to the situation. The major disadvantage of AUIs is their inconsistency, therefore different levels of adaptivity from intermediate to fully adaptive relating to the requirements (e.g. routine vs. non-routine tasks) could be offered [6]. Another approach to support the driver is to provide preconfigured functions relating to personal preferences and the situation for example by using information about the situation to predict the next destination to which the driver wants to navigate [4].

This saves additional steps within the user interaction. In [7] a support through situation-adaptive shortcuts of functions and the offer of autonomous execution of actions in recognized situations after a configuration through the driver is proposed. Similar is also the support of [2] who implemented a proactive recommendation system, which provides actively situation-related recommendations to the driver.

3. APPROACH

The referred approaches are not integrated in an overall architecture and therefore doesn't benefit from it. The AIDE architecture is an overall architecture but it is not designed to support the driver by providing an easy access to functions. If all approaches for specific functions are integrated in an overall architecture a prioritization is needed. Otherwise, when several support strategies address the driver at the same time, this would result in driver distraction as well.
In our approach we use the architecture of AIDE as a basis and extended the functionality of the ICA to identify the user needs and to deduce support possibilities. A scheme of our architecture is shown in figure 1.

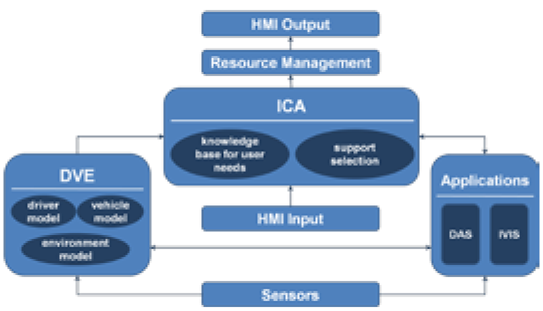

Figure 1: overall architecture related to AIDE

The situation is recognized by the DVE module, which is a central knowledge base for all elements in the architecture. The benefit of the DVE module as a central instance is the provision of extensive knowledge based on the exchange of knowledge. The recognized situation is used as an input for the ICA. The ICA of AIDE is extended by a component to detect user needs and a logic element to determine the best support for the identified driver needs. An example of such a process is illustrated in figure 2.

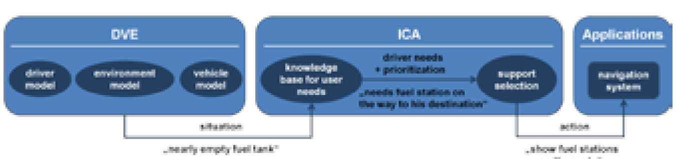

Figure 2: support of the driver

If several user needs are identified at the same time, the ICA decides which one should be prioritized related to the situation. The safety of the driver is the highest criteria for this prioritization. Depending on the driver needs, the driver is supported by the adaptation of the function set in the menu or by the execution of preconfigured actions with or without confirmation of the driver. Both reduce the complexity of the interaction by minimizing the number of operation steps. The preconfiguration of the actions is based on the situation, the observed user behavior in the past and knowledge from stereotypes. Using stereotypes reduces the learning phase of the ICA. To provide an efficient situation recognition and identification of driver needs, missing information, which is needed to make decisions, could be actively requested by the system.

4. CONCLUSION AND FUTURE WORK

We introduced an approach that provides a personalized and situation-adaptive support. This means to offer an easy and fast access to functions in an overall architecture with a prioritization of support possibilities depending on the situation. With our approach workload and distraction of the driver can be reduced.
In future we will further develop our approach and will have a deeper look into methods for prioritization and identification of user needs. Further concretion is planned with the help of use cases and requirements that need to be defined. As a result a prototype will be implemented and integrated in a driving simulator to evaluate the approach with the help of user studies.

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AmbiCar: Towards an in-vehicle ambient light display

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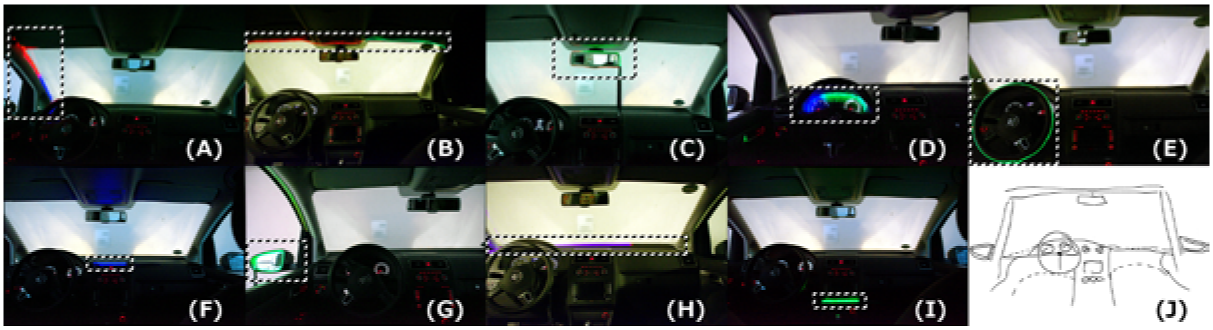

Figure 1: (A-I): Different locations for the ambient light display. (J): Basis for participants' sketches.

ABSTRACT

Several systems using different modalities have been introduced to assist drivers. We want to find out if peripheral vision is a less demanded cognitive resource while driving and therefore propose ambient light as an alternative modality for information presentation. In this paper, we propose different locations for an in-vehicle ambient light display and present first results of a survey regarding these locations.

Categories and Subject Descriptors

H.5.m [**INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)**]: MISCELLANEOUS

General Terms

Design; Human Factors; Experimentation.

Keywords

Ambient light display; peripheral interaction; in-vehicle.

1. INTRODUCTION

Many systems using different modalities for the driver-car interface have been developed to assist drivers (e.g. [1, 2, 3, 4, 5]). However, assistant systems that warn against critical situations without taking the driver's state into account (e.g. health parameters or cognitive load) may surprise drivers who are not aware of a critical situation. Considering this, we want to enhance the driver's awareness by continuously displaying the criticality of the current driving situation. Further, we do not want to increase the driver's mental workload and therefore use a modality that addresses a lowly demanded mental resource, following Wickens' theory on multiple resources [7]. Peripheral vision may be such a resource and was successfully addressed in other domains using ambient light (e.g. [6]). On the contrary, foveal vision is a separate resource and already highly demanded, for example to recognize hazards or signs. We want to find out if peripheral vision is suitable and propose ambient light as a modality for information presentation during driving.

2. ONLINE SURVEY

In a first step towards an ambient light display, we needed to find out where to place it. We conducted a brainwriting session with five drivers and extracted nine locations. Based on that, we implemented prototypes at these locations.

Light patterns were designed by defining dynamic changes of colour, brightness etc. of the LEDs. Snapshots of the display are shown in Figure 1. Based on videos and pictures of the prototypes, we created an online survey to answer the following questions: Where do participants think it was easy to perceive a light display ($Q1$)? Where would participants prefer to have a light display placed ($Q2$)?

We took this approach to receive feedback from more participants compared to conducting a lab study. While doing so, one has to keep in mind, that the dynamics of ambient light can not be mapped to images. Hence, participant's answers may differ from results coming from a real in-car setting. However, we will be able to focus on few locations while evaluating different light behaviours in future work.

2.1 Procedure

After an introduction to the objective of the survey, we asked for personal information, such as age or vehicle model.

Next, participants could watch videos of different light patterns at different locations to get an impression of what is possible. They were reminded that the survey is about locations of a light display and not about these light patterns.

For each location shown in Figure 1, an image consisting of seven examples of light patterns was presented. Participants could rate each location for its perceptibility ($Q1$) and the participant's preference ($Q2$) using a seven-point Likert-type scale and comment on it.

Afterwards, participants were asked to select their favourite or the option *none of the shown*. In addition, they could sketch their own ideas for a location and comment on it. Finally, they could give general feedback regarding the survey.

2.2 Results

58 people participated in the survey (38 male, 19 female, 1 without answer). Most participants (24) were between 24 and 30 years old. Most drivers (19) received their licence 5 to 10 years ago. 8 participants stated they do not drive, 12 drive less than 5,000km per year, 15 up to 10,000km, 11 up to 20,000km and 12 more than that.

We used Friedman's ANOVA to test our findings regarding $Q1$ and $Q2$ for significant effects. In addition, we performed Wilcoxon signed-rank tests to follow-up our findings and applied Holm corrections. Effect sizes were calculated using the formula $r = \frac{Z}{\sqrt{N}}$, where N is the total number of the samples, and among other results shown in table 1.

Likings and perceptibilities differed significantly ($\chi^2_l(8) = 88.9, p < .001$ resp. $\chi^2_p(8) = 128.6, p < .001$). *(D)* is the favourite location for 18 people. Next, *(H)* was preferred by 10 participants. Both locations' perceptibilities were rated higher than for most other locations, but don't differ significantly. *(G)* and *(I)* were the least preferred locations. The perceptibilities of both locations were rated significantly lower than any other location. Looking into the ratings for likings, the results of *(D)* are significantly higher than the ones of most other locations, reflecting the high number of votes. Interestingly though, *(F)* and *(H)* are on the same level, both having higher ratings than *(E)*, *(G)* and *(I)*, which retrieved comparably low ratings.

We used Kruskal–Wallis ANOVA to search for differences between groups of participants regarding $Q1$ and $Q2$, performed Mann–Whitney's U tests to follow up our findings and applied Holm corrections. We found several gender-, age- and experience-related differences. For example, female participants liked *(E)* more compared to male participants ($\tilde{x}_{lAM} = 2$, $\tilde{x}_{lAF} = 4$, $r = -.32$), while men liked *(A)* more ($\tilde{x}_{lEM} = 4$, $\tilde{x}_{lEW} = 2$, $r = .31$). Though the analysis is not yet finished, also within most of the groups *(D)* seems to be preferred, while *(I)* seems to be the least preferred location.

Looking into the participant's sketches, a heads-up display (HUD) integrated into the windscreen is the most proposed alternative so far beside variations of the presented locations. Further analysis of the survey is yet to be done.

	#	$\tilde{x}_p$	$\tilde{x}_l$	r_{pD}	r_{pG}	r_{pH}	r_{pI}	r_{lD}	r_{lF}	r_{lH}
A	5	5	4	*	.47	*	.44	-.34	*	*
B	2	5	4	-.36	.38	-.37	.44	-.46	*	-.3
C	4	4	3	-.36	.39	-.32	.39	-.39	*	*
D	18	5	5	–	.53	*	.52	–	*	.28
E	4	4	3	-.42	.35	-.36	.38	-.45	-.34	-.29
F	6	5	5	*	.4	*	.53	*	–	*
G	2	2	2	-.53	–	-.49	*	-.46	-.33	-.29
H	10	6	5	*	.49	–	.51	-.28	*	–
I	1	3	2	-.52	*	-.51	–	-.48	-.52	-.36

Table 1: Number of votes for favourite location (#), medians for perceptibilities and likings ($\tilde{x}_p$, $\tilde{x}_l$) and effect sizes (r_{pX}, r_{lX}) for significant differences to other locations ($p < .05$ after correction). Non-significant effects were marked with * or dropped. The names of the rows refer to the names of the locations given in Figure 1.

3. CONCLUSIONS AND FURTHER WORK

As a first step towards an in-vehicle ambient light display, we conducted a brainwriting session and an online survey to find a suitable location for the display. According to our findings so far, the best location is *At the dashboard (D)*.

After analysing our results, we will be able to limit the number of prototypes that are needed to evaluate the locations in a more realistic setting. Furthermore, with a large number of participants, we may be able to identify different groups of drivers that prefer different locations.

A short-term goal is to evaluate different prototypes using different light patterns to display information to the driver. In the future, we plan to use ambient light as an additional modality for a multimodal driver interface.

4. ACKNOWLEDGMENTS

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Tactile-Acoustic Devices for Automotive Safety Applications

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ABSTRACT

Tactile-acoustic devices represent a class of sensory augmentation technology that is typically considered as an assistive device for increasing access to movie or music soundtracks when hearing is limited or unavailable to an individual. However, the use of the skin as an input channel for critical information when the visual and auditory channels are engaged represents a new area of research for this technology. The paper presents preliminary arguments and motivation for expanding research into sensory augmentation with tactile-audio devices into automotive applications as a means to increase safety and awareness for drivers.

Categories and Subject Descriptors

B [**Hardware**]: B.4 Input/Output and Data Communications—*B.4.2 Input/Output Devices*

Keywords

Tactile-acoustic devices, driver engagement, attention, distraction reduction, multi-sensory interactions

1. INTRODUCTION

Computers have enabled researchers to explore the concept of sensory substitution or cross-modal interactions for many interesting and creative applications to assist people with disabilities access, navigate and interact with the environment using an alternative sensory modality to augment or replace vision and sound. But these technologies can also enhance perceptions and awareness for everyone, especially when our eyes and ears are overloaded with information while operating a vehicle. The sense of touch opens up a new form of sensory display that can provide increased access to environmental information in general, offering an novel form of extra-sensory information that can improve awareness and safety. This work introduces a new research initiative that explores the use of multi-modal tactile interfaces to increase awareness and reduce driver distraction.

Driver distraction and attention

Driving represents one of the most attention-intensive everyday activities we all engage in, and the technology we can now use to improve safety and awareness, like GPS displays, and ubiquitous access to email and phone calls actually place additional demands on our limited visual and auditory attention resources. Though these devices help us better navigate and keep connected while on the road, they serve to further distract us from the critical attention levels needed just to maintain our basic driving skills, and represent a growing problem for all drivers. Sensory augmentation of visual and audio information through the tactile senses represents an excellent opportunity to begin exploring ways to support this increasing influx of information that is presented to drivers. By leveraging the ability of the skin to receive and process information that is intended for our eyes and ears, we can start to offload some demands placed in our eyes and ears to the body.

2. BACKGROUND

Several years of research into sensory augmentation of sound to the tactile senses have revealed benefits worth exploring that can increase driver awareness and safety. A tactile acoustic device (TAD) transfers audio information directly to the body in an effort to emulate the human cochlea on the skin, and has demonstrated effective results in communicating characteristics of sound to the tactile senses for deaf and hard of hearing people [2]. Research into TADs also suggest that hearing people can just as effectively process sound information through the skin, which may have valuable applications in providing an alternative means of receiving information that is intended for the eyes and ears [3]. TADs present sound to the body using multiple audio-transducers in a similar way that our ears process audio signals. For example, most existing tactile systems tend to process signals within the low frequency spectrum, ranging from 60Hz to 200Hz [1]. However, these signals are already easily detected simply by placing your hand on a speaker, or along the door of a car when loud music is playing. TAD has shown that the skin has a much higher capacity for processing audio signals, and includes the entire range of the audio spectrum to provide a potential for creating a much higher resolution form of tactile-acoustic display format using the body. This, coupled with the available surface area of the skin provides the potential to create an exceptional alternative to delivering safety critical information to the driver without placing additional demands on our eyes and ears.

Motivation

Over the past 5 years, TADs have been explored as an assistive device, in addition to an entertainment enhancement system to augment sound from film, music, and gaming with tactile-sound. Studies suggest that augmenting audio-visual experiences with tactile-sound can increase awareness, emotional connections, immersion, and enjoyment for users, with the added benefit of providing accurate and important information about sound through the skin alone [4]. However, it is the gaming research that has led to this move towards automotive applications as a safety critical device. Early results from an ongoing series of usability studies involving the game GranTurismo 5 (GT5) and TADs suggest many significant benefits to driver performance, engagement, and commitment to the game with the addition of the tactile-sound. Although gaming is not the same as driving, the added attention, immersion, and information that drivers reported experiencing with the tactile-sound could be transferrable to the driving safety enhancement system. The TAD system presents the sounds from the game through chairs that are used by a driver and passenger in our gaming scenario. The study presents sound from the car engine, the road noise, and game music through the TAD, using different combinations for the study. Each of these sound sources can be clearly identified by users, and even slight changes or disruptions to the sound can have a profound impact on the users attention to that signal. This occurs even when all three sources of sound are presented through the TAD concurrently. All of our gaming participants preferred the TAD-enabled condition, with drivers reporting feeling increased heart rates and perceived improved scores in race times and precision in handling the vehicle. It is anticipated that similar effects will be transferrable to actual driver scenarios, and the goal is to evaluate these effects in an actual driving scenario to expand on the gaming research.

Research Goals

Results of previous research that show that the body can interpret a significant amount of information about sound through vibrations, including detecting emotional content of music [3], musical timbre [4] as well as the gender and intentionality of speech. Other forms of audio cues that are not directly based on sound have also been shown to be effective for providing critical information to drivers [1]. Using the TAD system as a tool for investigating and implementing tactile audio and audio-cues together in combinations and configurations that will potentially reduce driver distraction and increase awareness of their environment. Additional factors that will be explored and validated include determining optimal size and placement of transducers, effects of the integration of audio and non-audio signals, quantitative measures on driver attention and distraction, and optimal combinations of the multiple sources of audio signals.

Methodology

A combination of ethnography and empirical methods will be applied to support the hypotheses being proposed in this research, which focus on the use of multi-sensory stimulus as a means of increasing driver awareness, while reducing distraction. The TAD systems will be refined and adapted for use in automotive vehicles as a low cost, adaptable multi-sensory integration tool for investigating the nuances of tactile-audio and audio-cues for automotive applications. Biometrics, response times, and performance measures of drivers in the different sensory conditions will be considered, as well as driver perception, preference, and enjoyment reports, towards understanding the relationships and factors of the multi-sensory feedback system being proposed, and to explore tactile-sound as a new mode of information that can offer many distinct ways of providing vehicle operators with a new channel for receiving meaningful information from the environment, and from the automobile itself.

Prototype Development

A flexible and adaptable model of current TAD system will be developed based on early research results towards determining the critical factors of installation and integration into the automotive system. While a plug-and-play version is currently in use, the aim is to develop an integrated system that can be adapted to integrate seamlessly with the current and existing audio sources and automobile information systems including surround sound, road noise, driver alerts, communication, and other feedback sources. The hardware that drives the signal processing to the TAD can be powered using a 12V power outlet, the system comes with a suite of audio cables, splitters, and connecters to support access to different and multiple sources of audio signals to make experimental design more efficient and flexible.

3. NEXT STEPS

The auto-TAD is being used in actual driving scenarios now, and has begun to take shape as a robust experimental device that will be used in the upcoming research projects. In addition to testing and modifying the prototype, signal-processing studies will be conducted independently to provide a broader understanding of the combined sound and audio-cue signals that can support the hypotheses that tactile displays can improve driver safety, increase attention, and reduce distraction.

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Exploring aesthetics factors of gesture interaction in vehicles: An empirical study of in-car music player

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ABSTRACT
This paper aimed at exploring the aesthetic factors of gesture interaction in vehicles through the descriptions of the aesthetic experience of drivers to provide reference for the further study of the aesthetic of in-car gesture interaction and gesture design. Based on the analysis of the collected descriptions, we finally present a set of aesthetic factors of in-car gesture interaction that can influence driver's aesthetic experience.

Categories and Subject Descriptors
B.5.1 [**Design (e.g. Styles)**]: Gesture interaction-Aesthetic factors.

General Terms
Design, Experimentation

Keywords
In vehicle, Gesture Interaction, Aesthetic Factors, Music player

1. INTRODUCTION
As the functions and infotainments in vehicles increasing, gesture interaction is a promising solution to reduce the visual attention while driving [1]. Designers and researchers have put much effort in designing more intuitive and natural gestures in vehicles [2, 3]. Based on previous research, we propose to integrate *"aesthetic of interaction"* into the design and research process of gesture because *"aesthetics can be a powerful design driver that helps connect dynamic form, social and ethical aspects [4]"*. However, there is only a broad definition of the aesthetic of interaction as an area of research covering both the perspective of aesthetic experience and aesthetic expression [5]. Besides, there is no prior reference in the special scenario of in-vehicle.

In our point of view, to get the aesthetic factors that can influence driver's aesthetic experience is the first step to present a set of countable reference for the future definition of aesthetic of in-car gesture interaction and gesture design. Hence we plan to collect descriptions of drivers' aesthetic experience and qualitatively derive the aesthetic factors from the analyzed data. In the study, an elementary application of vehicle - music player was chosen to be the research object. A demo controlled with gesture (G-player) was developed. Using principles of aesthetic interaction as guideline, we derived drivers' semantic descriptions of aesthetic experiences in different aspects and finally conclude a set of aesthetic factors with the analysis methods.

2. METHODS
We adopted an empirical study by integrating methods of observation, interview, questionnaire, and participatory design. There were 18 Chinese participants in total consist of 9 male and 9 female, between the age of 20-49($\bar{M}$=30.22 SD=8.77). All of them are right-hander and have driver's license.

2.1.1 Data Collection Methods
We designed part of the controlling gestures (see Figure 1). The G-player built with Arduino was assembled besides a driving simulator in our lab. We did a pilot study to test the usability and revised the G-player's controlling parameter and position.

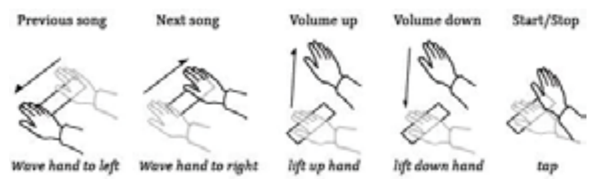

Figure1. The gestures of G-player

Firstly, drivers were asked to drive on the simulator and control the music player while driving. Then we encouraged drivers to design gestures for the functions and offered several optional gestures to choose. Researchers observed drivers' behaviors and recorded their words. Based on the observation, an interview was done to obtain further opinion of their experience of gesture controlling while driving. Questions in the interview were designed under the guidance of the aesthetic principles [4] to elicit participants' oral descriptions of their aesthetic experience, e.g. '*Where do you prefer to execute the gesture while driving?'* is guided by *'maximal effect with minimal means', 'What attributes of this gesture attracts you'* is guided by *'has satisfying dynamic form'*.

2.1.2 Analysis Methods
Descriptions were given in a variety of perspectives and were about different aspects of gestures. The basic method of dealing with the data is affinity diagram [6]. After three rounds of affinity building we were able to categorized similar descriptions into a group. Besides, a qualitative method of coding scheme [7] was adopted to transform the original categories of descriptions into the separately aesthetic factors.

Table1. Part of description's coding table

NO.	Conversation/Notes	Category
07-05	*"I don't want to looks like an idiot while I control the music"*	Social Aspects
09-10	*"I don't want to draw others' attention for the control."*	

3. RESULTS
The collected data included transcripts, video recording in three views, a set of gestures designed by participants and their subjective sequencing of gestures we provided. From these data

we selected 142 Chinese descriptions of in-car gestures referring participants' aesthetic experience. With the analyzing methods, we summarized two categories of aesthetic factors that can influence the drivers' aesthetic experience of in-car gesture interaction. Physical factors are mainly about the physical attributes of gestures while mental factors concerns drivers' subjective aesthetic experiences and feelings.

3.1.1 Physical Factors

Kinematic impulse. The kinematic impulse consists of gesture's weight and speed. Drivers suggest the gesture have proper weight and speed as gestures too strong or fast may impact the other hand holding the steering wheel and gestures too light or slow need more time to conduct and may distract them from driving.

Complexity. Complexity is related to the gesture's dimensionality and track. Some drivers don't like vertical gestures because it requires much more efforts by raising arm than gestures in other dimensions. Besides, most drivers prefer gestures with easier track.

Position. The position to conduct gesture in vehicle is vital for driver's experience because the available space for driver is limited. Their favorite position is the right and upper space of steering wheel. They mentioned this area is the most accessible and safest one to conduct gestures when driving.

Size. Size refers the range of gesture, which is closely related to the effort of conducting. Most drivers mentioned smaller gesture is better because it can be conducted with only wrist or forearm. Thus, it will save much effort.

3.1.2 Mental Factors

Social aspects. Social aspect refers to socio-cultural factors including descriptions about normality and trustworthy. Drivers care about how the gesture looks like by passengers and people outside of the vehicle. They want be normal and not draw others' attention while performing the task. Besides, the gesture should be reliable without any possible misoperation.

Gesture mapping. Gesture mapping means gesture should be coherent with function in the aspects of meaning, user's knowledge and experience, e.g. the previous experience of using a computer. Moreover, the gesture's meaning should also be coherent with the corresponding function.

Beauty. Beauty concerns driver's direct feelings of aesthetic gestures, which are related to the descriptions involving natural, elegant, fluency and gesture track. However, there is no agreement on the specific style of an aesthetic gesture for the various subjective perspectives. The distinction between male and female is huge, for a gesture considered to be elegant by female participants creates the opposite feelings to male. The track also affects the experience of gesture beauty. Generally, a smooth and fluent track without any sharp turn is thought to be beautiful while a decisive track is regarded to be ugly.

Mental workload. Mental workload is the efforts a driver put to understand, remember, recall and conduct a gesture while driving. It is related to the descriptions about track, comprehension, memory, and inaccuracy. As a gesture being more comprehensible, less accurate, easier to remember and recall, driver will put much less attention resources on controlling. Thus they will feel more relaxed and safer with gesture control in vehicle, which may greatly increase drivers' aesthetic experience.

4. DISCUSSION & FUTURE WORKS

In this paper we conducted an empirical study to collected drivers' aesthetic descriptions of their experience with aesthetic principles as guideline, and finally presented a set of aesthetic factors that can affect the aesthetic experiences of in-car gesture interaction. Our ultimate research goal is to get a definition of the aesthetic of in-car gesture interaction. The current work is the very first step to explore the theme.

The initial challenge for our work is whether the aesthetic factors can be derived from the descriptions of aesthetic experience. As the experience is the outcome of interaction design, we believe descriptions of aesthetic experience implied the factors that shape the final aesthetic experience, which can be a reference for further research and design. Another challenge is whether this can be a countable reference for designing gestures. The results are in a macro view and lack of specific details to help solving practical and complex design problems. What we proposed are only a small part of the whole. Besides, the relationship between physical factors and mental factors remains to be discussed as we did notice there are connections between them.

The future work is to enrich, revise and verify these aesthetics factors. To explore more aesthetic factors, we plan to conduct a larger scale of study on collecting gesture behaviors involved aesthetics. In order to verify and revise the credibility of these factors, we will adopt them as a design guide in a practical project to test their effect as references. Moreover, the present experiment was done with only Chinese participants and in a lab environment. We'll conduct a universal experiment involving people from other cultures in natural scenarios of driving to explore more countable aesthetic factors.

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Instruction or distraction in the driving school?

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ABSTRACT
In this paper we report an ongoing study of driving school practice. We recorded several hours of driving lessons in different environments, which we analyze with the Interaction Analysis method. Our initial analysis suggests that looking at how teachers make use of different communicative resources to instruct students in driving, can provide insights for the development of technologies that support drivers in managing distractions.

Categories and Subject Descriptors
J.4 [**Social and behavioral sciences**]: Sociology; K.6.1 [**Project and people management**] training.

Keywords
Driving schools, distractions, instructions, distruction management, driving.

1. INTRODUCTION
The theme of distraction is of great relevance in the design of automotive interfaces [2] [4]. Especially when designing supportive technologies for driving, great attention is dedicated to providing the right balance of information or entertainment, and avoiding disrupting the driver's attention from the road and the traffic environment. Recently, social scientists have contributed to the research on this theme, pointing out how most studies focus exclusively on interactions between drivers and technologies in isolation, with less attention to the contextual and equally important aspects of social interactions both as supportive of the driving task, but also as a source of distraction [3]. Acknowledging this point of view, we can provocatively think of social interaction as a prototype of an infotainment system, where car passengers actively participate in driving, (for example noticing aspects of the road and the traffic environment), or "provide entertainment", but are also a source of distractions that the driver is more or less compelled to attend to. But how do drivers learn to receive and respond to different stimuli? And how can these stimuli be provided? To investigate this, we undertook a study of a driving school practice, and analyzed how the interactions between learner and teacher evolve. With this, our intention is to better understand how experts skillfully provide information, and direct drivers attention to relevant features of the environment or the car, which could possibly inform the design of in-car information and entertainment systems.

2. THREE CAMERA SETUP
In our study, we followed a student learning to drive, from the very first lesson to the final test. The student (female, age 18) had never driven a car before. She was supervised by an instructor with 14 years of experience (Figure 1).

For documentation we used a set up of three miniature cameras

Figure 1. Driving instructor and student seen from front camera (Cam2).

(GoPro) placed inside the car to capture (1) the student actions, (2) the interactions between instructor and student and (3) the street view as seen from the driver, Figure 2. The lessons took place in two different environments and were recorded with two slightly different camera set-ups:

Closed driving range – Student alone in car: The first three lessons of driving are located in a closed driving range. The student is alone in the car, driving test paths under radio guidance provided by the instructor. In this case, the instructor is also supervising other students, and follows the students' performance from an observatory area in the center of the driving range. The student can hear everything the instructor says, both to her and to other students, but can't talk to the instructor. The car is equipped with two indicator lights on the roof: Orange when the student is touching the clutch, and red when the student is braking. The activities were recorded with 3 cameras inside the car and one tripod-mounted HD camera following the car from outside. Towards the end of the driving course the student returned to the driving range for additional lessons of skid training on prepared surface.

Traffic environment – Student with instructor: For the traffic training lessons the instructor sits next to the student to practice

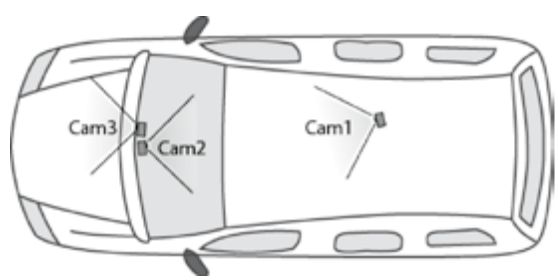

Figure 2. The placement of the 3 mini-cameras inside the car: Cam1 records student and teacher interactions with the car; Cam2 observes gaze and facial expressions; Cam3 registers the trafic environment.

Figure 3. Split-screen video allows analysis of movements and interactions from different points of view.

driving on urban and rural roads. The student drives according to the guidance provided verbally by the instructor. The lessons are individual, and the student and teacher talk freely. In this case, the set up of cameras was the same as in the closed driving range environment, but without the external view the car.

3. VIDEO ANALYSIS ON SPLIT SCREEN

In total, we collected 20 hours of footage covering 6 lessons each of 1,5 hour duration, over a span of 4 months. Of these lessons, 2 were from the closed driving range environment. To facilitate a detailed analysis of the data, we synchronized the videos into one split screen sequence to allow direct comparison of the three views, Figure 3. Greater priority was given to footage from Cam1, which best captured the interactions with the car and between student and instructor. The analysis is carried out with the Interaction Analysis approach [1]. Interaction analysis is a qualitative method with roots in ethnography and ethnomethodology, which makes use of video recordings as a basis for analysis of how people interact with each other, objects and the environment around them in everyday, naturally occurring interactions. Interaction Analysis focuses on looking at particular events in detail, and builds generalizations from the body of evidence that those particular events provide. The analysis is carried out by looking repeatedly at video recordings, without any preconceived theory about the data and its content. With recurring observations, the researchers can then identify foci of analysis, such as for example structures of events, temporal organization of activities, or the role of artefacts in interaction, which are then investigated further, with the help of accurate transcriptions.

4. INSTRUCTORS AS DISTRACTORS?

Based on an initial analysis, we identified two main foci of analysis that seem relevant for examining distraction and how to address it in car environments. Our main point of attention relates to the instructor. We observe that the instructor provides information to the student on multiple levels: (1) Body posture (‘put your hand on the gear shift’) (2) Car functions (‘break now’) (3) Car in context (‘place the car towards the center of the street’) (4) General driving practice (‘It’s important that you find a swift flow…’). Beyond teaching, the instructor also engages with the student in conversations that are unrelated to the driving task. Information is provided with different resources (talk, body posture, voice pitch) and with different timings. For example, the teacher might forewarn the rules necessary to approach a roundabout in advance, while providing instructions on the use of pedals during the action itself. In other instances, she might discuss general driving matters while pointing at elements of the environment, or directly intervening in the students’ driving performance (Figure 4).

Figure 4. In a roundabout, the instructor provides information on several levels, while at the same time intervening to correct the student’s path (Cam1).

A second focus relates to the student; how she coordinates the different actions required to drive the car and how she gives attention to the instructor. This aspect is interesting for analysis in relation to the interventions of the teacher. An example is how, when the teacher perceives that the student is apparently too concentrated on the gear stick, she attracts her attention (distracts her) on other aspects of the environment such as the back-mirror, or other cars at the side of the road. A full analysis is still in progress, but our preliminary hypotheses are that 1) We might be able to distinguish between different ways in which the instructor supports or intervenes in the driver’s performance, and what kind of information is related to these interventions. 2) We might be able to observe a development in how the student responds to the different requests given by the instructor. These observations can possibly be a resource to understand how drivers deal with external stimuli and how to support them, and also to learn from “experts” about different ways, timings and techniques to provide informational content to drivers.

5. SUPPORTING ACTIVE MANAGEMENT OF DISTRACTIONS

The aim of this study is to think of distractions as interactions that evolve over time, influenced by drivers responses in an active ongoing process, rather than think about “distractions” as identifiable episodes possibly occurring during a car drive. While it is true that the driving school case is peculiar in that the student has the duty to attend the instructor (and therefore does not need to evaluate whether or not the information she receives is relevant), the study should help us understand how people acquire the skill to manage interruptions. By uncovering the ways in which skilled trainers actively distract (and instruct) drivers, and how the latter develop skills for managing distractions, we hope to draw implication for the design of new user interfaces and car environments that – instead of aiming at eliminating sources of distraction – facilitate coordination and management of different source of distractions.

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Interactive Demos

Development of a Conversational Speech Interface Using Linguistic Grammars

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ABSTRACT

In the automotive environment, intuitive in-car speech interfaces are crucial in order to reduce driver distraction. The design of an intuitive speech interface poses a great challenge to the speech recognition and natural language understanding component of a speech dialog system since human language allows speakers to create an infinite number of sentences. In this paper, a linguistic grammar approach, which incorporates linguistic knowledge in the grammar design in order to develop flexible grammars, is presented. Based on this approach a conversational speech dialog system, which allows German users for booking a hotel has been developed.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

1. INTRODUCTION

Todays' in-car speech dialog systems (SDS) are command-based. Due to the novel in-car Internet access, the number of accessible applications in the car increases quickly. The cognitive load needed in order to control the SDS will rise with the number of available applications as the number of possible commands will also increase. Hence, a conversational and intuitive speech interface is necessary to ease voice-control and to reduce driver distraction. Apple's Siri, for example, allows users to speak with their mobile phone as if they would talk to a human being. However, usually, only the first step in the human-machine interaction can be performed by speech. After the first spoken utterance the user has to continue with haptic input to achieve his goal. In the automotive environment, a turn-by-turn conversational speech interface is targeted in order to allow the driver to keep hands on the wheel and eyes on the road.

The design of a conversational speech interface poses great challenges to the automatic speech recognition (ASR) and natural language understanding (NLU) modules of an SDS since "any speaker of a human language can produce [...] an infinite number of sentences"[1]. The human spoken language allows speakers to create sentences with the same meaning in many possible ways by e.g., using synonyms, reordering constituents or even concatenating phrases.

There are two main approaches to model the user's language for ASR[4]. Statistical language models (SLM) provide statistical information on word sequences and are used to predict the next word in a sentence. However, in order to generate a reliable language model, a huge amount of data is needed to train the SLM. In addition, there is no efficient way to semantically link the output of the SLMs with the NLU. The second approach is based on grammars, which use rules to model permissible word sequences. The design of a wide and flexible grammar is time-consuming and often legal word sequences, which were not anticipated, are ruled out or syntactical erroneous sentences are falsely accepted. However, grammar rules can simply be extended to deliver a semantic annotation of the recognized word sequence.

In this paper, a linguistic grammar approach, which incorporates linguistic knowledge in the grammar design, is presented. The ASR and the NLU component use separate grammars which are both based on the same linguistic grammar sources. In the next Section, the linguistic grammar concept is described. Based on this approach we developed a conversational SDS, which allows German users to book a hotel, which requires a wide and flexible grammar due to the various input parameters. The SDS prototype is described in Section 3 and finally, conclusions are drawn.

2. LINGUISTIC GRAMMAR CONCEPT

The linguistic grammar approach is based on several lexica of words and a set of syntax rules which is illustrated in Figure 1.

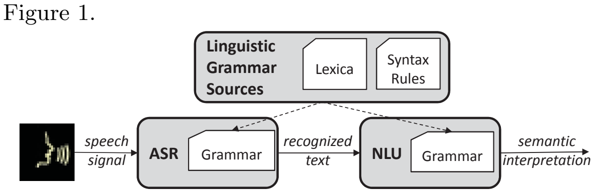

Figure 1: ***Linguistic Grammar Concept.***

There are lexica for each lexical category (verbs, determiners, nouns, etc.). Each lexicon contains a set of words and possible synonyms. Furthermore, each word in the lexica is labelled with its semantic meaning and its morphological properties. E.g., for each entry in the verb lexicon the verb form, the tense, the mode, the number and the person are specified (see Table 1).

The syntax rules describe how the words in the lexica can be concatenated to syntactic categories. For each combination, the lexical category and its required morphological properties are specified. A concatenation is valid if the morphological properties of the different words match. Thereby, it is ensured that only syntactical phrases are generated. Sample syntax rules are illustrated in Table 2.

The lexica and the syntax rules should be defined in a general way in order to reuse these components for future gram-

Table 1: ***Sample Verb Lexica.***

Lexical Entry	Semantics	Verb Form	Tense	Mode	No.	Person
suchen (search)	search	infinitive				
suche (search)	search	finite	present	ind.	sg	first
suche (search)	search	finite	present	imp.	sg	first
finden (find)	search	infinitive				

mars. The lingustic grammar sources are employed to generate grammars for the language model of the ASR module and the keyphrase spotting technology of the NLU module. The specification of the different grammars and their employment are explained in the following.

Table 2: ***Sample Syntax Rules.***

Syntact. Cat.	Ex.	Lex. Cat.	Case	No.	Gend.
NP (Noun Phrase)	*ein Hotel (a hotel)*	Determiner	nom	sg	neutr
		Noun	nom	sg	neutr
NP (Noun Phrase)	*die Hotels (the hotels)*	Determiner	nom	pl	fem
		Noun	nom	pl	fem
PP (Prepositional Phrase)	*in einem Hotel (in a hotel)*	Preposition	dat		
		Determiner	dat	sg	masc
		Noun	dat	sg	neutr

2.1 ASR Grammar

Based on the lexica and the syntax rules the grammar of the ASR can be specified. The desired syntax rules and the required semantic values of the constituents have to be indicated in order to specify a grammar rule:

$search= *V[search] + NP[theNumber, roomType]*
+ PP[in, starHotel]

By indicating the semantic value of the constituents only synonyms with the same meaning are selected. The syntax rules help to generate all possible syntactical sentences. The above-mentioned sample rule produces numerous sentences with the same meaning, for example (English: "Search for 2 double rooms in a 4-star hotel"):

"Suche 2 Doppelzimmer in einem 4-Sterne-Hotel."

"Suche 2 Doppelzimmer in einem Hotel mit 4 Sternen."

"Finde 2 Doppelzimmer in einem 4-Sterne-Hotel."

Complex use cases like a hotel booking require the user to indicate multiple search parameters in order to retrieve a list of hotels. These search parameters can occur in different orders and in different combinations which still have to be taken into consideration and have to be specified. However, the use of syntax rules reduces this problem to a permutation of constituents which can be generated automatically.

2.2 NLU Grammar

In order to interpret the recognized utterance, the NLU component uses phrase spotting techniques based on the lexica entries and the syntax rules. A sample rule for interpreting the hotel category is illustrated in the following:

$hotelCategory = *PP[in, starHotel] | NP[starHotel] |N[starHotel]*

By applying the above-mentioned phrase spotting rule all phrases like "in einem 4-Sterne-Hotel", "ein 4-Sterne-Hotel", "4-Sterne-Hotel" and possible synonym phrases are interpreted. The NLU phrase spotting is independent from the employed recognizer engine. Thus, the engine can be replaced and the SDS stays flexible towards new recognizer technologies.

3. SDS PROTOTYPE

Based on this linguistic grammar approach we developed a conversational SDS, which allows German users to book a hotel. The design of the SDS's grammar is based on speech data we collected in an online user study[2]. For ASR we employ Nuance's VoCon®3200[1] embedded speech recognizer. A graphical user interface has been designed in order to support the speech dialog.

In order to evaluate our approach we compare the performance of a grammar-based ASR engine based on our approach with SLM-based ASR engines. Furthermore, we investigate the respective interpretation result when sending the ASR output to the NLU module based on our grammar approach. The grammar-based ASR engine is Nuance's VoCon®3200[3] embedded speech recognizer. In addition, we access offboard Nuance's Dragon NaturallySpeaking[2] and WebSearch server[4] which both employ domain-unspecific SLMs. In a preliminary lab experiment we collected 177 conversational utterances with 24 people (m/w=15/9, average age=29) driving in a simulator using our prototype at an early development stage. We use this corpus to evaluate the performance of the ASR engines on word accuracy (WA) [3]. Furthermore, the concept accuracy (CA) [3] of the NLU module is assessed which is crucial to a successful SDS performance. The results are illustrated in Table 3.

Table 3: ***Evaluation Results.***

Recognizer Engine	WA	CA
Grammar-Based VoCon	*81.3%*	72.6%
SLM-based Dragon	*88.4%*	72.4%
SLM-based WebSearch	*88.7%*	75.5%

The results show that SLM-based ASR performs better than grammar-based which is due to out-of-vocabulary words missing in the lexica. Training of the SLMs on the specific domain would further improve the WA. Concerning CA, all setups achieve similar results whereof the WebSearch recognizer performs best since its ASR result contains the most semantically relevant constituents. Despite the decreased ASR performance, with our grammar-based approach these constituents, which are crucial for successful NLU processing, are recognized.

4. CONCLUSIONS

In this paper, we presented a linguistic grammar approach, which incorporates linguistic knowledge in the grammar design of an SDS. The ASR and the NLU component use separate grammars which are both based on the same linguistic grammar sources. Based on this approach a conversational SDS, which allows German users for booking a hotel has been developed. The ASR and NLU performance results proved our concept and the flexibility of our approach.

Within the scope of the EU funding project GetHomeSafe the SDS prototype is evaluated in driving simulation studies on usability and its impact on driving performance.

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Comparison of Different Touchless Gesture Interactions in the Car Cockpit

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ABSTRACT

Nowadays, various assistance- and communication systems belong to the standard equipment of a modern car cockpit. Those days are gone where the whole infotainment-system consists of a traditional car radio with physical buttons and controllers. In recent years different new and innovative functions and features have been added in advanced car cockpits, e.g. navigation systems, Mp3-, CD- and DVD players. All of these infotainment functions need to be controlled by different human-computer interactions, e.g. spin controller in the center console, keystrokes or touchscreens. While interacting with these systems permanent visual attention on the display is imperious necessary to coordinate the finger for data entries. Therefore, diversions of gaze are provoked which could cause dangerous consequences while driving. Different studies reported negative user evaluations concerning usability, user satisfaction and distribution of attention while driving and interacting with different car systems (e.g. Lansdown, 2001; Ablassmeier, 2009). These studies were usually based on well-established, market-ready systems like spin controller and touchscreens.

But how should advance car systems be designed to enable effective and secure human-computer interaction while driving? One obvious and often suggested approach to interact with in-car systems is voice entry. But most of these systems are still buggy and not fully operative (Akyol, Libuda & Kraiss, 2001). But for some time past a new research area of cockpit interaction came up that focuses on intuitive, touchless gesture interactions within car cockpits. Researchers and developers expect advantages regarding distraction, efficiency and driving safety from it (Rees, 2013). Touchless gestures could be executed independent of the operator control module within three-dimensional room.

With our current research study we developed a navigation system prototype, which could be operated by humans through different intuitive, touchless gestures. Subsequently, we analyzed and compared three different ways of touchless interactions without any driving task to analyze very basic human-interaction abilities.

The user-defined task was to enter six predefined addresses (country/city/street), which were announced by the study manager into a navigation system. After each trial (3) the participants (n = 23) had to fill out the NASA-TLX questionnaire (Hart & Staveland, 1988). All participants had to operate with the navigation system in three different ways of touchless gesture interaction: (A) handwriting entries, (B) virtual keyboard entries (time) and (C) virtual keyboard entries (click) in randomized order. Virtual keyboard (time) means that the users had to pause 0,5 seconds above the interesting letter on the integrated virtual on-screen keyboard of Windows (see figure 1, above) to select this one. Virtual keyboard (click) needed a so-called „pinching“-pose (merging thumb and trigger finger) to select the interesting letter (see video for more details). For touchless handwriting data entries the „MyScript Stylus“ software of VisionObjects (see figure 1, below) was used. The software is able to transcribe handwritten data into formal text (on the navigation system interface).

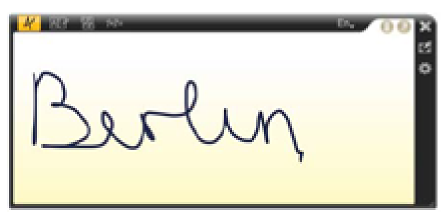

Figure 1. On-screen keyboard of Windows (above) and MyScript Stylus input field (below)

Hence, the following hardware system environment was set up (see figure 2). A Microsoft Kinect camera was used as principal component to identify hand gesture interactions. The integrated software program „3Gear Systems“ allows a more precisely defined hand, finger and gesture detection. By integrating the application „Mouse3Button“ touchless

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mouse over interactions are possible by moving the right hand in the desired direction and the application supports the left mouse click function by the „pinching"-pose, too.

Figure 2. Experimental set-up and hardware system environment

Objective performances and subjective users' impressions were analyzed and compared with each other. The independent variable on doing so is the way of touchless gesture interaction (A, B, C) and the interesting dependent variables are: task completion time, task errors and subjective data (NASA-TLX).

Table 1. Average values and standard deviation of user performances and subjective data

	A	B	C
Time	1025s (348)	483s (120)	433s (144)
Errors	11,7 (8)	2,6 (3)	4,5 (3)
NASA-TLX	58,9 (22)	35,8 (17)	39,5 (18)

Because of technical issues six participants dropped out during handwriting condition (A), therefore only 15 participants were analyzed regarding objective performances (see video for detailed error description). *Task times* were analyzed using repeated measures ANOVA, with touchless gesture conditions (A, B, C) as independent variable. Thereby, significant differences were found between virtual keyboard condition B (time) and handwriting condition A, as well as virtual keyboard condition C (click) and handwriting condition A ($F(2,14) = 41.94$, $p < 0.001$, $n^2part = 0.75$). Both keyboard entries were obviously faster than handwriting entries (see table 1). *Task errors* were also analyzed using a repeated measure ANOVA, with touchless gesture conditions (A, B, C) as independent variable. Significant differences were found between handwriting and both virtual keyboard conditions ($F(2,14) = 16.28$, $p < 0.005$, $n^2part = 0.54$). Mean task errors were highest in the handwriting condition (A), compared to the keyboard conditions B and C (see table 1). The NASA-TLX questionnaire was used to analyze *subjective users` impressions* when interacting with the three different gestural conditions (A, B, C). Users rated the virtual keyboard conditions (B, C) more pleasant and less physically and mental demanding than handwriting condition ($F(2,21) = 16.92$, $p < 0.005$, $n^2part = 0.45$). Overall, no noteworthy differences between the two virtual keyboard conditions (B and C) were found regarding objective performances or subjective data (see table 1).

This study is part of a research series, which analyzes human-cockpit interactions in the automotive domain within virtual test environments. To do so, basic research is necessary regarding common and innovative in-car interaction modalities. Previously touch interfaces and center console spin controller were analyzed. Here, we examined the most promising touchless gesture input options for in-car navigation systems. In summary, the experiment showed advantages for touchless entries via virtual on-screen keyboards (time and click) when entering navigation destinations. They are significantly faster, more precise and less error-prone compared with handwriting gestures. Additionally, we recommend virtual keyboard gestures by click function (pinching pose) for dual-task conditions, because less visual attention should be necessary. But further research is required, especially while driving, before touchless gesture interactions could be implemented in real cars.

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