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AutomotiveUI 2012
PORTSMOUTH NH

AutomotiveUI 2012

4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications
in-cooperation with ACM SIGCHI

October 17—19, 2012
Portsmouth, New Hampshire, US

ADJUNCT PROCEEDINGS

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„Industrial Showcase“

Organizers:

Andrew L. Kun	General Chair
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A Year of Global Connected Car Research

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ABSTRACT
This industry paper describes a year of UX research into the Connected Car by the Autos UX team at Microsoft Corporation.

Keywords
UX, UI, HMI, HCI, Connected Car, Ethnography, Usability, Benchmarking, Autos, Cars

1. FRAMING UP THE UX CHALLENGE
Creating a great user experience for the car of tomorrow is not an autos problem: it's a connected life challenge. Understanding the users of the in car infotainment features is not the same as understanding who buys a car, or who drives a car, though they are related.

We approached it as a connected consumer device (with its special safety, ergonomic constraints), looking at it at 3 levels: the actual interface, the interactions within the car, the connections with the other devices in the life of driver and passengers.

2. ROLE OF RESEARCH (Academic vs. Industry Perspective)
The UX research needs to support 3 groups, each with their own needs. This is a major difference to research in an academic environment. The three groups are 1) product planners and managers, 2) the design team, 3) developers and testers. Each needs answers to different types of question: who are our users and what should we build? How should it work? Does it work as intended?

Different research deliverables answer these different questions. Competitive reviews, user model, scenarios and prototypes, benchmarking – each type of study supplies insights to these questions.

Often researchers who are used to an academic context are challenged in moving into an industrial research role, because they do not understand the different needs of their audience. Put simply, they need to provide insights, not simply data, to professionals who need answers to questions NOW. To the extent what they say can help their stakeholders make decisions and move forward is the extent they are successful. If they can provide new insights that drive a product forward, that is best. Arnie Lund often underlined this point to me: running studies, no matter how elegantly, is not enough. Providing insights and A-ha moments is the currency for success.

In practice, this means staying close with the different stakeholders, being embedded with teams where possible, and being part of a team. Going off and returning 3 months later with data is typically effective. There are other practical guidelines for presenting research in a way that is better received in industry.

- stay involved with the team(s), understand what questions they want answers to (that you can answer)

- understand when the team needs which answers, and deliver within that window

- help the team 'get the feel' of users

- lead with insights and recommendations, backed by data. Do not lead presentations by describing methodology or data. "Be an analysis ninja, not a reporting squirrel" (Avinash Kaushik).

- cultivate a peer network of cross-disciplinary experts. E.g. in my case, experts in Phone, Speech, Bing, MSR, OEMs

- work with a designer who can make the most important deliverables highly visually impactful.

3. THE RESEARCH PROGRAM
From initial conversations with planning and PM stakeholders, we saw that the most important question was: who are our users of the infotainment system. We wanted a global picture of this, based on real data. Existing knowledge was mostly lacking by being older than two years, limited to the US, or focused on human behavior such as purchasing. No research we found had squarely focused on "users of infotainment technology". Fortunately it was well within our skillset to do so.

Other goals of the program were to help planning, PM, design, dev and test in understanding what should the connected car of the future do, how should it work, and how well do connected cars work today.

Here is a short description of the activities we conducted this past 12 months:

1. Dealership visits: picking a chosen set of competitors, one designer and one researcher arranged a dealership visit to spend time in the car and be driven around it. This low cost study started the ball rolling.

2. Competitive review: secondary research on the competitors, presented in an attractive format that the wider team can pick up and refer to.

3. Field studies (1): we contacted a number (in the dozens) of individuals and families in the local area, whom we interviewed in their home, had a tour of their car, and then rode along with. This ethnography was recorded and analyzed, and – as hoped – showed many surprising and quirky ways that real people arrange their in car infotainment technology. For example, we took photos

of where people put their cell phones: the range of locations is wide.

4. Global quantitative study: using a survey that asked about attitudes, wants and behaviors, and large sample size (n>1000), we did a factor analysis to identify the main ways that differentiate users of the infotainment systems. We found two principal axes. This was the basis for our user model, which we distilled into a set of 5 personas. I chose that approximate number of personas from past experience: personas need to be sticky to be effective, and having too many lessens that. That said, we do recognize a wider variety of users (secondary personas).

   It's important to note that the way the field studies and global survey were sequenced was deliberate: the field studies helped inform what questions we ask people in the survey, and helped interpret the findings. Sequencing makes a big difference. Our timelines were tight, so it was a close run thing to get them to happen sequentially, not concurrently.

   Two important things we did differently to help the user model be understand and accepted were to a) create a very simple 'back of the napkin' version (kudos Dan Roam) and b) use a professional illustrator to create custom images, rather than relying on boringly-ubiquitous stock images or model shots.

5. Field studies (2) in Shanghai. Asian megacities are fascinating places to drive, and provide unique challenges to a modern infotainment system: intense traffic, creative use of the road by drivers and pedestrians, rapidly expanding road networks, raised highways, additional levels of licensing and permits, a tech savvy young populace oriented towards digital media.

6. Benchmarking usability: we chose two systems to run through a rigorous process of usability benchmarking. We identified a core set of tasks, and had n ~70 people run through them. We measured task success rates, task times, lostness and qualitative measures such as perceptions of ease of use and satisfaction. We also took the opportunity to interview people on their experience owning the systems. This study yielded a data-driven sense of which system is better (put simplistically) and what types of errors prevent people from better task completion. It also provides metrics against which to measure in the future.

There is a mix of methods above: small and large scale, qual and quant, lab and field. They were sequenced for the maximum effectiveness (given constraints of budget, time, staff – as always). They were intended to answer the main questions about who are our users, what should the connected car of the future do, how should it work, and how well do connected cars work today.

4. THE NEXT TWELVE MONTHS

As the project moves forward, different types of research activities come to the fore. For example, as our design team starts to work on concrete designs, we need to create and test prototypes. As a researcher, I am switching gears into working as part of the design team who are producing various levels of design concepts and prototypes.

5. IMAGES OF THE RESEARCH

The following is a selection of images that captures some of the feel of being part of this research program.

Taking photographs and short videos during 'Dealership Visits', to capture initial impressions of the systems.

Field studies showed up the sheer variety of ways that people arrange their devices in the car, e.g. where the phone is placed, or how people rig up their sweet tunes.

Using illustrations created specially for the project enables a flexibility and a very precise capturing of the feeling of users' experience. It is also eye-catching, and thus 'sticky'.

The extensive use of design boards in the design space of the Autos UX team. Constant sharing, review and crit of designs is part of the daily rhythm.

6. SUMMARY

We aim to execute a research plan is well balanced amongst its methods, to help triangulate and interpret findings, and focused on answering the most impactful questions for our stakeholders – which are not just the design team but include planning, product management, dev and test.

7. ACKNOWLEDGMENTS

Particular thanks goes to the internal stakeholders who, with their extensive experience, have helped guide and sponsor the UX research efforts this last year: Walter Sullivan, Jay Loney, Tim Sellers, Steve Bridgeland, Stef Tomko.

OpenDS: A new open-source driving simulator for research

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ABSTRACT

In this paper we describe the industrial showcase *OpenDS*, a cross-platform, open-source driving simulation software for research. *OpenDS* is based on open-source components and will be distributed under open-source license on January 2nd 2013. The development of the software is fostered by the EU-project *GetHomeSafe*[1]. Furthermore, *OpenDS* receives additional funding for a requirement analysis and its distribution through the *Intelligent Mobility and Transportation Systems* action line of *EIT ICT Labs*. Commercial service and support is provided by the start-up company *white_c*[2].

Categories and Subject Descriptors

D.3.0 [**General**]

General Terms

Design, Economics, Experimentation, Human Factors

Keywords

Open-source driving simulation, simulator, driving performance metrics

1. INTRODUCTION

As full-fledged driving simulation software for the evaluation of automotive applications is high in price and low cost simulators often lack of extensibility, *OpenDS* was initiated to provide a basic simulation toolkit to the researcher community free of charge. In the following, we present the underlying framework *jMonkeyEngine* and introduce the main features of our driving simulation solution.

[1] http://www.gethomesafe-fp7.eu/

[2] http://www.white-c.com

Figure 1: The official OpenDS Logo.

2. UNDERLYING FRAMEWORK

The proposed driving simulation software is based on *jMonkeyEngine*[3] (*jME*), a high performance scene graph based graphics API. This open-source framework has been implemented in Java and has built up a reputation in game development. Its default renderer, the *Lightweight Java Game Library* (LWJGL), enables full OpenGL 2 through OpenGL 4 support. In version 3.0, the *jME* framework uses *jBullet*, a Java port of the *Bullet Physics* library, in use by top industry developers. Wrapping *Bullet Physics* library into *jME3* objects assures easy interaction and future updates can include support for native bullet, including GPU acceleration. *jBullet* is a multi-threaded physics engine which allows mesh-accurate collision shapes and enables the experience of forces such as acceleration, friction, torque, gravity and centrifugal forces during simulation. The support of several common model formats allows the simulator to load almost any 3D environment. Further features of *jME's* renderer are support of different lighting options (per-pixel lighting, multi-pass lighting, Phong lighting, tangent shading, and reflection), texturing (multi-texturing through shaders), and the capability to model special effects such as smoke, fire, rain, snow etc. Supported post processing and 2D filter effects are reflective water, shadow mapping, high dynamic range rendering, screen space ambient occlusion, light scattering, fog, and depth of field blur. *Nifty GUI* integration enables an easy-to-use toolkit for designing platform independent graphical user interfaces within the rendering frame, which is used for menus and message boxes during simulation. Concerning the use with *OpenDS*, *jME's* GUI node (speedometer and revmeter panels), multiple view ports (rear-view mirror), and basic audio support for playing positional and directional sounds, are rather useful.

[3] http://www.jmonkeyengine.org

Figure 2: The lab setting on Saarland University Campus. Fixed-base simulator running *OpenDS* with three projectors (120 degrees field of view) and connection to CAN-bus.

Figure 3: Driving through fog.

3. ARCHITECTURE

OpenDS consists of three major components: the driving task editor, the simulator, and the drive analyzer. With the graphical driving task editor, which is not to be confused with a map editor, the user can load an empty map model and place further objects; e.g., driving car, road signs, traffic lights, and vehicles. Moreover, car properties and events, which will be triggered in the simulator at run time, can be specified.

After finishing a driving task, it can be stored in XML format in order to provide the data for the simulation component, in which the given map model will be rendered and attached to the physics engine for realistic simulation. Currently, the main features of the extensible simulator implementation are different capabilities to control traffic lights (pre-defined cycles, red/green on approach, interactive external control), simulation of road traffic and different weather conditions, and a realistic engine and transmission model, which can be used to compute the fuel consumption from the current pedal state considering the power needed to overcome rolling resistance, air resistance, inertia, and potential energy, as well as the engine's inner friction.

Furthermore, events which have been defined in the driving task can be triggered under the given conditions; e.g., set the driving car's position, let objects appear/disappear, move vehicles, perform reaction measurements, play a sound file, etc. The reaction data recorded in this way can be visualized for example as a bar chart with the integrated *Jasper Report* module and exported to text or PDF format.

The third major component of *OpenDS* is the drive analyzer, which is able to visualize the car data recorded during a drive several times per second; e.g., position, direction, speed, and pedal states. It enables the experimenter to recreate the exact simulation environment from an earlier drive in order to analyze the car's state in every position. Furthermore, the car's driven route can be compared to a pre-defined normative track in order to compute the deviation, which can be considered as a measure of driving performance.

In order to facilitate a realistic simulation, our simulator not only provides an interface for game controllers, but also a CAN-interface for connecting to real cars, which enables the simulator to request car properties – like steering angle and pedal states – and to provide the in-car devices with simulation values. To increase the driving experience, *OpenDS* supports multiple screen outputs, which can be used for 180 degree projection (see Figure 2).

The most recent modular extension of the simulation component is the *Continuous Tracking and Reaction (ConTRe)* Task, in which the driving car itself is detached from the physics simulation and set up to follow pre-defined waypoints at a given speed instead. The driver's task performance is measured in terms of reaction times upon suddenly appearing red or green traffic lights as well as by measuring the deviation of a user-controlled cylinder from a computer-controlled target cylinder, where the user is instructed to get both in alignment by turning the steering wheel.

4. INDUSTRIAL SHOWCASE

We will demonstrate the *OpenDS* software with a desktop setting consisting of a computer screen and gaming steering wheel / pedals. We will also offer registration for pre-releases as well as priority access to the first open-source release on January 2nd 2013.

Inter alia, the *EIT ICT Labs* partners *German Research Center for Artificial Intelligence (DFKI)* and *Saarland University* (in the areas of sports science and construction design) launched a collaboration with the goal to develop motorsports-specific performance diagnostics which will be integrated into *OpenDS*. The 15-year-old regional kart race vice-champion and simulator expert Chiara Messina, who is also partner of the collaboration, has already conducted first tests with *OpenDS* revealing significantly shorter reaction times than experienced drivers.

5. ACKNOWLEDGMENTS

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„Tutorials“

Organizers:

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Tutorial: Introduction to Automotive User Interfaces

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ABSTRACT

The tutorial introduces the field of automotive user interfaces, as an interdisciplinary effort to create effective means for humans to interact with cars. Major factors, such as safety, usability, and user experience that guide the design and development are discussed. Based on a design space for interaction in the car the range of input and output options and available modalities are outlined. References to selected methods and tools for the design and evaluation of automotive interactive systems are given.

Keywords

Automotive, design space, safety, user experience, UX, tutorial.

1. INTRODUCTION

Looking back at the developments in the car industry it is apparent that over the last 20 year the user interfaces (UIs) in cars have dramatically changed. Early cars till the 1980ies typically followed a simple design principle: providing for each function a dedicated mechanical or electrical controller and for each output a dedicated display. With an increase in functionality this approach does not scale and car manufacturer introduced new interaction concepts, ranging from mechanical multi-purpose controllers to touch screen interfaces. With this transition operating the functions in a car became in many aspects very similar to human computer interaction (HCI). Entertainment, information systems, and increasingly assistive systems are essentially computers. It is foreseeable that in the near future even primary and secondary controls (for driving and driving related tasks) will be computer mediated. This shift requires re-thinking how automotive UIs are designed and evaluated [1], herby drawing from experience in mechanical engineering, car design, and HCI.

The context of use in the car is well defined and many external requirements are well understood and stakes are high. Drivers must not be distracted from the driving task, they should be kept alert and engaged, safety is paramount as failure may be deadly for the driver, passenger, or to others. Orthogonal to these requirements it is important to recognize that driving a car is for many people an enjoyable activity at times. Cars are partly bought for the experience and their image and manufacturer aim at providing a superior user experience. In HCI designing a particular user experience is a core topic [2], and hence methods can be appropriated to be used in the design of in-vehicle UIs.

Users bring mobile devices into the car and use them while driving, e.g., music players, navigation devices, and smart phones. These external devices compete with systems in the car but may also cooperate with the infrastructure in the car (e.g., controllers, speakers). Hence, considerations for automotive UIs are not limited to systems in the car, but are also applicable for mobile devices that are used in the car. Additionally, mobile devices, with their much shorter innovation cycles, are a driver for innovation in the in-car systems as they increase users' expectations.

2. OVERVIEW OF THE TUTORIAL

The tutorial introduces the characteristics of UIs in the car and highlights specific requirements that arise in the driving context. Functions and tasks requiring UIs and the types of applications drivers and passengers interact with are discussed and classified. With a design space [3] the spatial arrangement of user interface elements, available input devices and output elements, as well as implicit and explicit interaction modalities, and their implications on the driver are presented.

Using examples of novel user interfaces (e.g., a gesture interface [4] and gaze based interaction [5]) commonly used tools and methods for evaluating automotive UIs are outlined and their suitability is discussed. Topics include quantifying driver distraction with LCT and driving simulators, measuring impact the driver' cognitive load, and assessing gaze-behavior and physiological parameters while driving and interacting.

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Tutorial: Voice and Multimodal Interaction in the Car

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ABSTRACT

We present a tutorial on voice and multimodal user interfaces in the automotive context. After briefly explaining the technology behind automatic speech recognition (ASR) and text-to-speech (TTS) systems, we will explore the benefits of such systems for reducing driver distraction. Recent trends toward natural-language and multimodal interfaces will also be discussed. Throughout the tutorial we will point out key research results and commercial deployments that merit further reading and study.

Keywords

Speech; voice; ASR; TTS; automotive; multimodal; multimodality; natural language understanding; NLU; voice user interfaces; VUI; driver distraction

1. INTRODUCTION

In the eyes- and hands-busy environment of a moving vehicle, speech input and output has been trusted for over a decade as a safe and effective alternative to manual-visual interaction. This talk examines the roots and branches of voice I/O in cars, including, importantly, how voice can most thoughtfully be combined with other input and output modalities to enhance the overall automotive user experience.

2. OVERVIEW OF THE TUTORIAL

After a brief introduction to ASR and TTS core technologies, the tutorial will cover both commercial deployments and research results in the arena of automotive voice I/O.

We will examine studies that demonstrate the benefits of voice over manual interaction, but then we will take the "devil's advocate" position that a good manual-visual interface is better than a bad voice interface. This will serve as an introduction to voice user interface (VUI) design, a little-understood discipline which is equal parts art and science.

Next we will discuss the trend towards natural language understanding (NLU) voice interfaces, those in which users can speak to the ASR system as if they were speaking to a real person, that is using flexible and verbose sentence structure rather than a stilted-sounding command jargon.

Finally we will survey the literature on multimodal interaction, in which voice, tactile and gestural inputs are combined in various ways with audible, haptic and graphical outputs.

At the close of the talk, participants will be invited to speculate on how NLU and multimodality might push automotive voice interfaces even further into the mainstream, and how the academic community might foster this process—or sound notes of alarm if such systems are being implemented in ways that cause too much driver distraction.

3. SUGGESTED READING

The mathematical underpinnings of contemporary ASR and TTS are discussed in [6] and [4]. [3] offers a more application-focused ASR tutorial. An important survey of voice interfaces' effects on drivers' performance is [1], and [5] examines the role that ASR accuracy plays. [7] covers several crucial VUI design guidelines, and [2] and [8] discuss easy-to-implement forms of multimodality that confer significant usability advantages.

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Tutorial: Driver Distraction

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ABSTRACT

This tutorial will briefly introduce: (1) the evolution of driver distraction, (2) key definitions that have been proposed, (3) research methods used in the assessment of distracted driving, (4) the sensitivity of different techniques for measuring user interface demand, e.g. eye tracking, physiological monitoring, task and driving performance, (5) differences in the expression of visual, manipulative and cognitive demands on driving behavior, and (6) current governmental and industrial efforts to reduce distracted driving.

Keywords

Eye-tracking, physiology, driver behavior, task performance, safety

1. INTRODUCTION

The topic of distracted driving has been around since the early days of the automobile. In 1930 Nicholas Trott wrote in the New York Times, "A grave problem that developed in New Hampshire… now has all the motor-vehicle commissioners of the eastern states in a wax. It's whether radios should be allowed on cars. Some states don't want to permit them at all—say they distract the driver and disturb the peace…The [Massachusetts] commissioner thinks the things should be shut off while you are driving…The whole problem is getting very complex, but the upshot is that you'll probably be allowed to take your radio anywhere, with possibly some restriction on the times when you can play it." The technologies that can distract drivers have arguably increased in complexity since Trott's day, but the debate on what interactions are appropriate to complete safely while driving remains largely intact today. While thousands of articles have been written on the topic, it is essential that researchers consider numerous factors when interpreting the literature.

2. OVERVIEW OF THE TUTORIAL

Traditional, experimental research on distracted driving has largely focuses on assessing behavior changes with a moderate to high distraction task, e.g. drivers react more slowly when on a cell phone [6]. In other lines of research effects of demands are difficult to interpret, as attentive drivers may not fully engage in the task at hand [2]. The optimization of interfaces to minimize driver distraction requires a broader understudying of the problem. The larger question is, at what level of demand does a driver's behavior begin to be affected? Recent work [2, 4] shows that driver behavior is impacted by the simple activity of repeating a series of numbers (0-back).

The content of this tutorial will be geared towards providing participants with an overview of important considerations in the development of empirical research and the interpretation of previous research on distracted driving. Emphasis will be placed on understanding the appropriate use of techniques to provide sensitive measures of driver behavior. Illustrations of previous research will be presented where appropriate. Effort will be placed on providing attendees with an understanding of the effective use of different techniques for measuring demand and potential pitfalls.

3. SUGGESTED READING

For a comprehensive discussion on factors involved with driver distraction [3] is a good desk reference. Suggested reading in preparation for this tutorial include the topic of task duration [1], eye tracking and glance based analysis of visual demands [5], and the impact of cognitive demands on physiology, visual attention and driving performance [2, 4].

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Tutorial: In-vehicle UI Standards

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ABSTRACT

This tutorial describes (1) the guidelines, standards, and other documents that influence the design and testing of automotive user interfaces, (2) what they contain, (3) how they are created, (4) how to find them, and (5) which are most important. Given special attention are documents from the International Standards Organization (ISO Technical Committees 22, 159, and 204), the US Department of Transportation (especially the visual-manual distraction guidelines), and the Society of Automotive Engineers (SAE) Safety and Human Factors Steering Committee.

Keywords

distraction, NHTSA visual-manual guidelines, ISO 16673, ITU, SAE J2364, SAE J2365, user interface design and testing

1. INTRODUCTION

Research, such as that on automotive user interfaces, is more likely to affect interface design and evaluation if studies use test conditions and methods specified in standards, and then reference those standards. Authors writing research papers referencing standards benefit because their papers are consequently cited in standards. Further, standards writers benefit because standards are based on more research, and practitioners benefit because they learn of cited standards (when reading research papers) of which they are otherwise unaware.

In an review of the 25 papers presented at the 2011 Automotive UI Conference, the author found that only 2 papers that fully cited relevant standards, though for some papers there were no relevant standards [1]. In some cases, this was because the topic was quite new, in other cases because application was limited.

The author believes that sometimes standards were not cited because authors were unaware of which standards were relevant. This tutorial for Auto-UI authors and others will make that less likely in the future. See also references [2,3].

2. OVERVIEW OF THE TUTORIAL

This tutorial begins by describing standards-like documents that exist (guidelines, best practices, recommended practices, standards, regulations, etc.), how they differ, and the sections they typically contain, using SAE J2364 as an example. This leads to a discussion of how standards are developed, so researchers can understand when and how their work could be referenced.

To aid researchers in making that connection, how to find relevant standards is described, using the ISO and SAE web sites as examples. Finally, the most important standards for automotive user interfaces are identified. They include the US Department of Transportation visual-manual distraction guidelines, SAE Recommended Practice J2364 and many other documents from the SAE Safety and Human Factors Steering Committee, ISO standard 16673, other documents from ISO Technical Committee 22/Subcommittee 13 (Ergonomics of Road Vehicles), and other documents from ISO Technical Committees 204 (Intelligent Transportation Systems) and 159 (Ergonomics), as well as the International Telecommunications Union (ITU).

3. SUGGESTED READING

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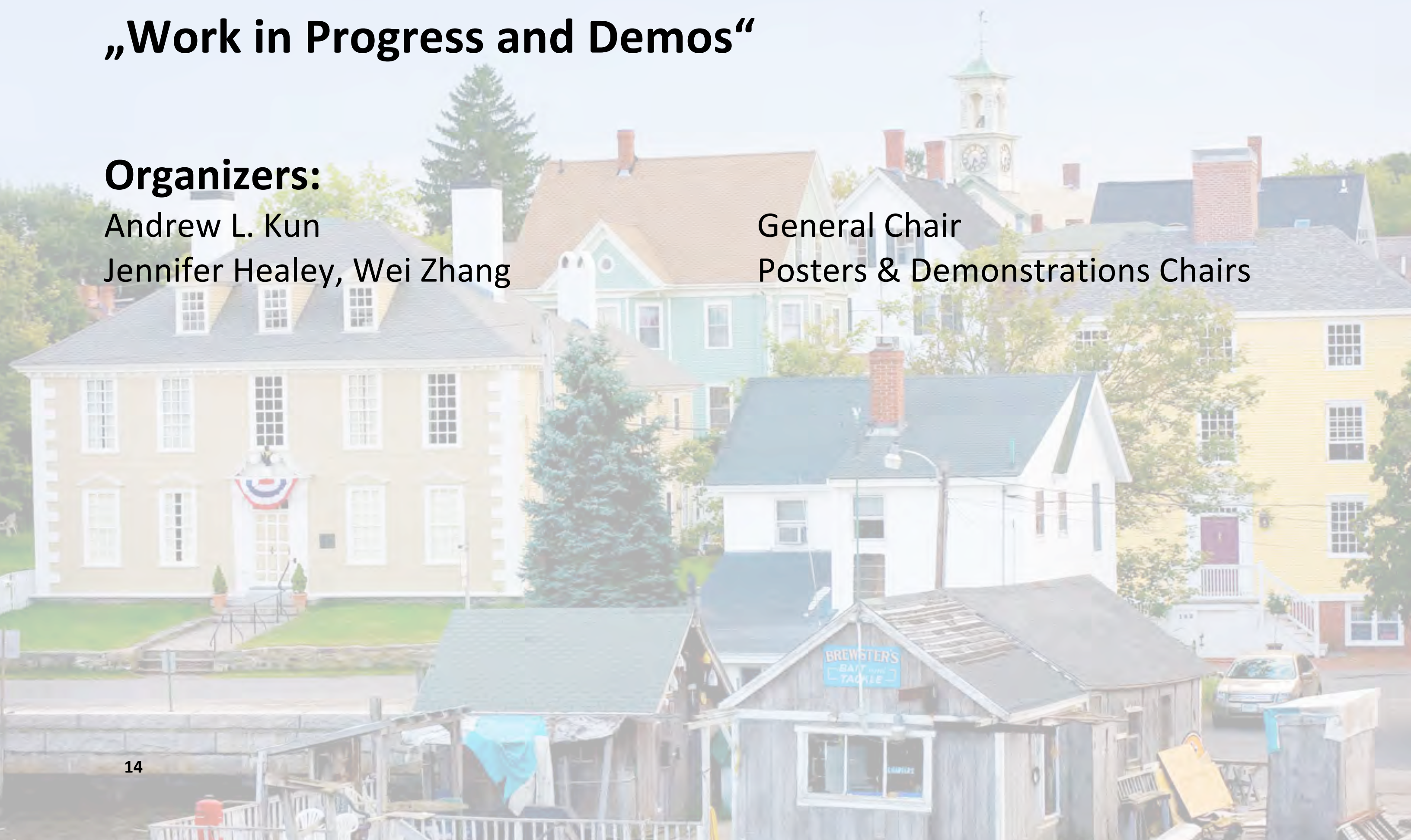

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Situation-Aware Personalization of Automotive User Interfaces

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ABSTRACT

This paper presents an interactive prototype of an automotive user interface that changes its behavior depending on the situation-dependent user preferences. In a first step, the interactive prototype gathers user information implicitly by observing the situation-dependent interaction behavior. Well-known contextual personalized features like situation-aware navigational shortcuts and situation-aware automated routines are used at the second step to support the user either with the presentation of a situation-dependent list of shortcuts or by an situation-aware automatic execution of commonly used functionality. Additionally, the interactive prototype is extended by a real-world driving simulator in order to experience the contextual personalization in real-time.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Prototyping

Keywords

Adaptive user interface; Automotive user interface; Context-aware; Personalization; Situation-aware

1. INTERACTIVE PROTOTYPE

Nowadays, modern in-car-infotainment systems offer a wide range of features which are popular in the area of home-entertainment systems or mobile devices like smartphones or tablets. But the technological progress also affects the way an user interacts with an automotive user interface. In the past, on-board computers were controlled by a limited set of feature-fixed hard-key buttons whereas modern on-board computers are operated by joystick-like central command units or speech commands. Thus, the handling is getting more complex and it becomes challenging to provide additional functionality without an accompanying decrease of usability. But normally, the user only utilizes a small amount of features. Therefore, a modern in-car-infotainment system should be able to adapt its user interface to the users needs. In certain cases commonly used features should be accessed easily or shown on top in order to reduce the cognitive load and distraction induced by navigating in complex menu structures. The automotive user interface presented in this paper observes the situation-dependent user behavior, builds up a situation-aware user model and modifies its structure based on the detected preferences. Hence, frequently used functions within a given environment are either shown within a list of shortcuts or being executed automatically.

Figure 1: Upper left: Real-world driving simulator; Upper right: Situation-aware automotive user interface; Lower left: Steering wheel; Lower right: Central command unit

1.1 Adaptive Automotive User Interface

The prototypical automotive user interface comprises a main screen with the commonly known menu structure and an additional screen on top showing the situation-aware navigational shortcuts [2]. A built-in navigation and audio system as well as an internet browser can be used by a test subject e.g. to enter a destination address, to change the radio station or to open web sites. A background service gathers all user interactions that are supposed to be relevant for the contextual personalization. These relevant user interactions are being grouped by their corresponding environments and stored within a situation-aware user model. The reader is referred to [4] for a detailed description of the rule-based user modeling approach.

If the user approaches a situation in which the user usually e.g. changes the radio station, a shortcut will be pre-

Figure 2: Situation-aware navigational shortcuts based on radio station and web site preferences.

sented within the list of contextual personalized shortcuts (see figure 2). The shortcut consists of an icon representing the basic functionality e.g. symbol of a radio antenna and the parametrization e.g. radio station name placed as text beneath the symbol. In each situation, the number of shortcuts presented in the list is limited to 4. Each shortcut is executed by pressing one of four hard-key buttons which are placed in front of the joystick of the central command unit. Executing a radio shortcut will directly set up the audio system to listen to the corresponding radio station. In this case, the user is relieved of the burden of the time-consuming navigation in the menu in search of the radio application.

Alternatively, a situation-dependent preference can also be used to automate the corresponding task. But the automatically detected preferences are only estimations made by the background service. Therefore, some of the preferences might not represent the situation-dependent user behavior in a correct manner. Prior to being automated, every situation-dependent preference will be listed in an additional feedback view in order to avoid the automation of tasks that are based on inappropriate preferences. The feedback view comprises a list of newly recommended and labeled situation-dependent preferences and their corresponding situations visualized by e.g. a map [1] or a list of the affected days of the week (see figure 3). If the user feels comfortable with a certain recommendation, it can be labeled as being a favorite preference. The automation of a situation-dependent task can be activated by enabling a favorite preference. While approaching a situation that is known to be relevant concerning a favorite preference, the automotive user interface signalizes an upcoming automation by showing a dialog box. It comprises a textual representation of the task, the remaining time until the automation gets executed and a button which can be used to cancel an automation. In a future version, an acoustic signal together with a confirming or aborting speech command might be used as well to signalize and approve an automation.

1.2 Simulation of User Behavior

Testing or demonstrating the abilities of an adaptive automotive user interface is challenging because all situation-dependent adaptations occur after a learning period of variable length and only within a certain context. Furthermore, the user interactions need to be variable concerning the duration or order of the individual interaction steps.

For demonstrating purposes, the learning period can be decreased manually in order to adapt the user interface immediately after detecting only a less amount of similar user interactions. But for the proper execution of a situation-aware personalization it is still required either to carry out the demonstration within a real car with its context-related sensors or to present the user interface in conjunction with a real-time simulation environment for context-related information generation. Following the latter approach, the presented interactive prototype is connected with a separately implemented real-world driving simulator [1] for the simulation of context-related information like the position of the car, the time of day or the level of fuel (see figure 1). Using the real-world driving simulator together with the prototypical automotive user interface makes it possible to experience a contextual personalized automotive user interface within a lab environment. A user study concerning the usefulness of both types of contextual personalized features was conducted based on the use of the prototypical automotive user interface and the driving simulator [1].

For testing purposes, the user behavior can also be simulated automatically in order to investigate the user interface behavior over a long period of time. This kind of simulation is based on a model of scenario-specific user interactions [3].

[1]The prototypical automotive user interface and the driving simulator make use of the Google Maps API: https://developers.google.com/maps/

Figure 3: Recommended situation-dependent radio station preferences within the feedback view.

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COPE1 – Taking Control over EV Range

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ABSTRACT
A problem for electric vehicles (EVs) is that available battery technologies limit the driving range and might cause range anxiety, and as technology stands now, this problem will be present for many years to come. As a result, it is important to design tools that could easily help users overcome range anxiety issues. Design of such technology can take advantage of the experience accumulated by drivers who have already coped with this problem for many years. In this paper, we describe a coping strategy observed among some more experienced EV drivers, as well as, why this strategy is powerful, and demonstrate a first attempt to utilize it in design.

Keywords
Coping strategies; electric vehicle information system; energy management; information visualization; interaction design; range anxiety.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

1. INTRODUCTION
In the electric vehicle (EV) use context, range awareness, or lack thereof, manifests itself through the phenomenon referred to as *range anxiety* [1, 4]. Range anxiety is an anxiety or fear of not reaching a target before the battery is empty, which can occur while driving or prior to driving as the user worries about later planned trips. The main cause for this problem is that EVs 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 8 hours in normal power plugs and a minimum of about 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 a trip-planning mistake, or even make the driver become stuck if discovered too late. While there is hope for improving battery technology in the future, current knowledge does not offer cheap manageable solutions for improving battery performance.

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 [2]. However, these types of calculations are problematic, as they tend to require knowledge about the future. Therefore, we are now researching alternative ways of dealing with range anxiety.

We address this problem by doing interaction design based on coping strategies developed among experienced drivers and reshape the user interface to meet the need of overcoming range

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Figure 1. Nissan Leaf EV driver demonstrate calculations of required energy efficiency for traveling 10 km using 1 battery bar (1,5 kWh).

Figure 2. COPE1. Circles represent locations, blue have been selected in a sequence connected with lines. Required energy efficiency is displayed in the lower right corner.

anxiety. In this paper, we will describe the coping strategy we encountered with experienced drivers and why it is powerful approach, as well as, illustrate a first attempt to utilize it in design.

2. OBSERVATION OF A COPING STRATEGY
When conducting field studies meeting experienced EV drivers, we encountered a range-anxiety-coping-strategy among one of them that appeared efficient to us, although yet relatively simple to perform. This driver had a few years experience through contacts, as a board member of the Swedish national EV interest group, and had also owned a Nissan Leaf for 3 months at the time.

The coping strategy can be described with the following vignette. The experienced EV driver was going to drop off the researcher at the airport and then drive home again. First, he looked up the distance back and forth to the airport (total distance). Secondly, he checked how many "bars" he had left in his Nissan Leaf user interface (Figure 1), each of those is worth 1.5kWh and there is a total of 12 (+2 hidden ones that provide sufficient security, as known by Nissan Leaf expert drivers [3]), which means he could approximate how much energy he got in the battery. Thirdly, he used his smartphone to do the following calculation:

[energy in battery(kWh)] / [total distance (km)] = [required energy efficiency (kWh/km)]

Lastly, he reset the "Energy Economy" (also kWh/km) figure in the existing Nissan Leaf interface. After this, he was ready to drive to the airport. In this particular case, he had calculated that he needed to drive with an energy efficiency of a maximum of 0.15kWh/km to be able to do the trip safely. When we arrived at the airport, he had 39km home and the cars own distance-left-to-empty estimation (often called the guess-o-meter) signaled 43km. This would normally be a typical cause for range anxiety, however, when we talked about this fact and range anxiety, he quickly replied:

"as long as I stick to the 0.15 (kWh/km) I will make it…don't worry about it".

In this situation, we believe that this strategy really demonstrated its potential in terms of easing range anxiety. It is also notable, that the strategy somewhat looks beyond the complexity of the world as in elevation, wind, number of passengers and so on, as the user can continuously adjust driving in relation to the required efficiency. In this sense, the strategy becomes a proactive and continuous tool, rather than a guess about how far one could reach (as the distance-left-to-empty meter) or our earlier work [2].

However, to be able to execute such a strategy, the user needs to know a few things about the EV and the world.

1. Know about the strategy in the first place.
2. How long is the desired route?
3. How much energy do I have?
4. How do I execute the calculation?
5. Where to get energy efficiency for comparison?

All of which, could be easily supported by the EV user interface to support both new and experienced EV drivers.

3. DESIGN RATIONALE

Based on our observation, we decided to design a prototype to begin to explore how this coping strategy could be used in design, and to further explore the values of such a strategy in the EV UI. We also assume the following to help set a direction of the design:

a) People have a limited set of locations relevant for driving, and a good understanding of where they are.

b) Users do not want to spend time on planning for everyday driving; this type of tools should be effortless.

c) Planning can take place both in-car or elsewhere on an external device connected to the EV UI.

4. COPE1 – COPING STRATEGY PROTOTYPE 1

Our prototype COPE1 (Figure 2) is implemented using HTML5 and Processing.js and runs in any browser. In its current state we have mainly ran it in a browser on our computers to try out the idea, but it is intended for use on an iPad or similar tablet devices.

The prototype provides the user with the possibility to add locations important to them using a map. We imagine that important locations might be anything from the user's home, to workplace or charging stations. A circular area in the design represents each location and the distribution is loosely based on the real map location. With loosely we mean that we try to put them on the right location, but if two areas intersect they will slowly move away from each other, similar to the London Underground topological maps designed by Harry Beck in 1931. This is done to avoid "hidden" locations and thereby improve accessibility and the interaction with regards to our rationale: it should be effortless and quick to set up a plan.

When the user has added some locations it is possible to tap on a location to set a starting point that will be highlighted purple. When a starting point is set, the size of the other locations are updated in relation to the distance between the starting point and each location, in other words, the further away, the smaller location. This is to provide some feedback on the distances and thereby hint on the amount of energy required to reach them.

After the starting point is set, the user can begin to set a route by adding a sequence of locations. The end location will be highlighted yellow, and the route will be connected with a line that gradually shifts in color from purple (start) to yellow (end) to provide some feedback on directions. If the user wants to drive back and forth between locations, lines will be separated to maintain a clear visual of all fare-stages.

In the lower right corner, the prototype displays the energy efficiency required to complete the whole route based on the energy in the battery and the total distance of the selected route. In its current state, the EV is always fully charged, latter this will be updated with the actual state of charge of the EV.

All in all, setting up a route can be done in seconds, even more complex routes, and the system automatically computes the distance and required efficiency for the route.

5. DISCUSSION

The range anxiety coping strategy that we are considering in this paper shows an important potential in that current energy efficiency can be computed only with data coming from the car. This is a great advantage in relation to other forms of range anxiety help, which need to take into account data from outside the car to provide range information, such as map data, weather data, traffic data, etc. [2].

However, *planning* based on energy efficiency will not be accurate if it is only based on the driving distance and the current charge, as our drivers have done it. Indeed if our airport driver would have met a traffic jam in cold weather on his way back from the airport, his remaining energy (and therefore the energy efficiency he has planned for) would not have been enough, as energy needed for the headlights and car heating decrease the energy efficiency and they are also conflicting with the strategy of driving slow to spare energy. Still, even in adverse conditions as long-time traffic jams, the energy efficiency required to reach the target can be computed with in-car information, thus arguing for the efficiency of this coping strategy.

6. FUTURE WORK

We are currently investigating the placement of a moving object (the car) on the topological map without disturbing interaction. When this is done, the starting point will be automatically set based on the location of the EV. This also requires that the sizes (representing distance) of the locations updates as the EV moves.

Another challenge we are currently addressing is the lowest energy efficiency that is actually theoretically and practically manageable, taking into account factors that affect energy efficiency, such as heating, speed and lighting. For instance, a low energy efficiency might require that the user drive unacceptably slow, which may also be illegal on some roads.

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A Layout-based Estimation of Presentation Complexity

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ABSTRACT

The complexity of a user interface indicates how demanding its use will be, which is a crucial fact in scenarios where cognitive resources are valuable, such as while driving a vehicle. Detailed research has been conducted on the parameters that can be modified to improve the perception of in-car presentations by the driver. However, less is known about quantifying the impact of a concrete interface. We propose a bottom-up approach for estimating the complexity of the composition of objects on a screen, which can be combined with previous research results. A first version of a formal mark-up is proposed and its upcoming evaluation is described. More results will be available at the conference.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Applications**]: User Interfaces; H1.2 [**User/Machine Systems**]: Human factors—*complexity measures, performance measures*

General Terms

Theory

Keywords

cognitive load, presentation complexity, automotive information systems

1. RELATED WORK

The motivation for our work is the understanding of the relationship between the interface presented to the user, especially in high-demand situations, and the impact on the workload, including distraction from other, potentially more critical tasks. Literature confirms that a distinct relationship exists.

[10] performed two experiments of taxing selective attention processes on the efficiency of working memory processes in relation to normal aging. The results show that the presence of task-irrelevant information disrupted the working memory process, which could be measured to a greater extent in older than in younger adults. In conclusion, it is suggested that distraction disrupts the ability to maintain a coherent stream of goal-directed thought and action in general and should be avoided for in-car presentations.

[8] performed a study aiming at investigating the driver's ability to detect the deceleration of the car ahead, while executing a mobile phone related task. The authors claim that neither hands-free nor voice-controlled phone interfaces could significantly remove security problems associated with the use of mobile phones in the car.

[7] performed a study on the difference between vocal commands and virtual sound cues while navigating without sound. The effects were observed both with and without cognitive load on the subject. Their hypothesis was that sound would cause less cognitive load than spoken spatial commands. No significant difference was found in low-load condition, but significant difference in the high load condition, where the navigation task could be completed in less time when guided by audio cues instead of spatial language. As consequence to the field of automotive research, navigation systems should switch from spoken commands to well known sound cues when the driver encounters high cognitive load.

[9] investigated the effects of divided hearing attention. Subjects were asked to interact with an audio menu, while being exposed to another audio source. Under low cognitive load, the spatial audio technique was preferred and the interruption technique significantly less considered. Conversely on high cognitive load, these preferences were reversed.

While these studies examined certain aspects of the interaction between presentation and user in very specific cases, they do not yet reveal much about the properties of this interaction. Imbeau et al. performed an extensive user study on formal parameters which influence the perception of presented information [6, 5]. In a simulated vehicle, forty subjects were asked to read aloud words presented in eight second intervals on two displays which emulate written legends on an instrument panel while driving at nighttime conditions. The characteristics of the words presented were varied

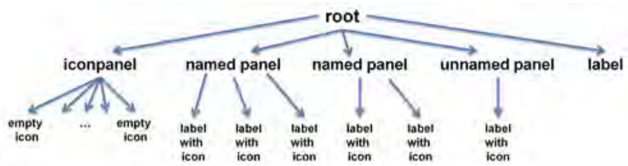

Figure 1: The HMI as component structure tree.

in four different dimensions and combinations thereof. The variations include word complexity[1], chromaticities, brightness, and character size. The main goal of their work was to "provide designers with integrated quantitative performance data that will help them answer design questions and evaluate design alternatives". Using their model, user responses to various changes in parameters can be predicted "offline". [2] describe an approach to speech-driven UIs for drivers. The authors discuss the impact of linguistic complexity on cognitive load.

2. ANNOTATED COMPLEX. ESTIMATION

The previous literature review clearly indicates that considerable work has been put into analyzing parameters and conditions to streamline and improve the delivery of information to the driver of a vehicle. Especially [6] and [5] probed every conceivable parameter of in-car display design very thoroughly. On the other hand, their work is based on displays of the late eighties, and technological progress did not stop there. While the emphasis back then was on font size, color, brightness, contrast and word complexity, we now also have to deal with sophisticated layouts. Also, the use of a touch screen and virtual buttons on the screen was not considered then. General parameters were in the focus of the research while UI composition was neglected.

Layout is commonly defined as the part of graphic design that deals in the arrangement and style treatment of elements. A programming interface for a user interface, such as for instance Java Swing, provides several types of containers ("layout managers") for the developer to choose from. In defining the Annotated Complexity Estimation procedure ACE, we reverse the top down layout manager process to a bottom up aggregating model of complexities. The nested structure of a user interface can be represented as a tree structure, where each edge represents a container-contents relationship. The main layout manager is located at the root of the tree. Other layout managers may be nested in it. When analyzing the complexity of a layout, we can start at the leaves of that tree and work our may up to the top and accumulate the complexity until we reach the top of that tree. The simplest leaf, or more precise: component, we encounter is for instance a label or an icon. A label has a text of a certain complexity, and it might contain an additional small icon making it more complex. Rudimentary components can be grouped in a panel. The panel has a size in terms of the number of elements it contains, it might have a visual boundary, such as a border line, that makes it easier to perceive as a unit. Panels again might be combined to a higher level panel. Following this combining of elements further, we reach the root of the tree and the component that fills the whole screen. The aim is to find a numerical value describing the visual complexity of that root node. In figure 1, the structure of the HMI is presented as a component tree. In order to apply the ACE procedure, the leaves of the tree have to be annotated with numerical values, and for all non-leaf nodes an aggregation formula has to be specified. In order to automate the procedure, we transform the tree into a machine-readable XML annotation.

An interim consent was achieved as shown in Table 1. It will be the objective of further experiments to determine its validity or learn more accurate projections. Using this procedure, the overall complexity calculated for this example is 9.3. Note that this is based only on structural complexity of the user interface design. In a more refined approach, all the parameters identified in [6] have to be considered as well. We will attempt to verify our approach in an experiment, where users estimate the complexity of given presentations on a scale of 1 to 10. Using a development data set, parameters of ACE will be refined and tested again with a control data set. After showing the general applicability of the approach, we will refine and extend it to more GUI elements and refine it according to the related work presented here. The resulting system will be used in the SiAM system.

component	basic complexity	feature	added complexity
label	0.1	text=true	+0.5
		icon=true	+0.4
icon	0.1	type=empty	+0.0
		type=icon	+0.5
		type=static	+0.2
		metainfo=text	+0.4
panel	$0 + \sum$ child nodes	decoration=framed	+0.2
		decoration=none	+0.5
		metainfo=named	+0.2
		metainfo=none	+0.5

Table 1: Calculating values for ACE evaluation

[1]Imbeau et al. define word complexity by the frequency of word occurrence and the number of syllables

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Brain Sensing with fNIRS in the Car

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ABSTRACT
We propose using functional near-infrared spectroscopy (fNIRS) to measure brain activity during driving tasks. Functional NIRS is a relatively new brain sensing technology that is portable and non-invasive, making it possible to sense brain activity in environments that would not be possible using most traditional imaging techniques. This provides us with the opportunity to better understand changes in cognitive state during mobile tasks, such as driving. Our research aims to integrate fNIRS into an existing driving test bed and explore signal processing and classification algorithms to study the sensitivity of fNIRS brain sensing to changes in the driver's workload level in real-time.

Categories and Subject Descriptors
H.1.2 **[User/Machine Systems]**: Human factors

General Terms
Human Factors.

Keywords
Brain sensing; Driving; fNIRS; Physiological computing.

1. INTRODUCTION
Drivers have numerous demands and distractions while navigating the vehicle, both on the road as well as from people and technology within the vehicle. As new interfaces and technologies are introduced into vehicles, it is critical to assess the cognitive workload that the driver is experiencing to ensure safe operation of the vehicle. An understanding of the changing cognitive state of a driver in real-time can inform the design of in-vehicle interfaces.

Recent work has looked at measuring physiological signals such as heart rate, respiration and skin conductance [5]. Functional near-infrared spectroscopy (Figure 1) [1,11] recently has been used in human-computer interaction research to assess cognitive states in real-time during tasks on a computer [2,7,8,9]. Because fNIRS is portable and non-invasive, it has potential for use in a car, and a few studies have taken steps in this direction [3,6,10]. In addition, it may offer complementary information to other sensors.

In our work, we are integrating fNIRS sensing with other physiological and environmental sensors. With this, we can study whether fNIRS has promise as an assessment method for in-vehicle tasks. Specifically, we are investigating the sensitivity of fNIRS to working memory demands, using an established task called the n-back task.

2. FNIRS BACKGROUND
Functional near-infrared spectroscopy provides a measure of oxygenated and deoxygenated blood in the cortex. Light of near-infrared wavelengths is sent into the brain cortex where it scatters and some is absorbed by the oxygenated and deoxygenated hemoglobin in that area of the brain. A sensitive light detector can determine the intensity of the light that returns back to the surface of the head. This raw light intensity value can be used to calculate the oxygenation in the blood, which also indicates brain activity in that area.

3. EXPERIMENTS
We plan to study working memory demands that come from secondary tasks while driving. While there is a wide range of secondary tasks that a driver may perform, we will use the n-back task, which has established capacity for eliciting scaled levels of working memory demand [4,5]. This serves as a proxy for various secondary tasks that a driver may perform. Our experiments will be conducted using a driving simulation environment equipped with fNIRS. The fNIRS data will be analyzed to determine whether there are patterns in the data that correlate with varying levels of working memory demands. We have the simulation and fNIRS system in place, and we are making the final preparations for running the studies.

3.1 Simulation Environment
The driving simulator consists of a fixed-base, full-cab Volkswagen New Beetle situated in front of an 8 × 8ft projection screen (Figure 2). Participants have an approximately 40-degree view of a virtual environment at a resolution of 1024 × 768 pixels. Graphical updates to the virtual world are computed by using Systems Technology Inc. STISIM Drive and STISIM Open Module based upon a driver's interaction with the wheel, brake, and accelerator. Additional feedback to the driver is provided through the wheel's force feedback system and auditory cues. Custom data acquisition software supports time-based triggering of visual and auditory stimuli and is used to present prerecorded instructions and items for the cognitive task while subjects are in the simulator.

3.2 fNIRS Setup
The fNIRS device in the vehicle is a multichannel frequency domain OxiplexTS from ISS Inc. (Champaign, IL). Two probes will be placed on the forehead to measure the two hemispheres of the anterior prefrontal cortex (Figure 1). The source-detector distanc-

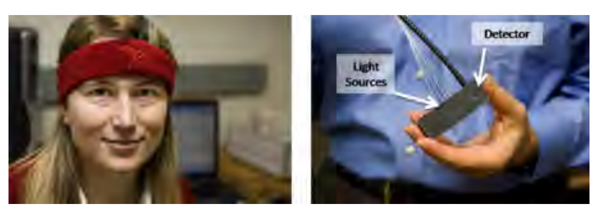

Figure 1. Two fNIRS sensors (right) are attached under a headband (left). There are four near-infrared light sources and a light detector on each sensor.

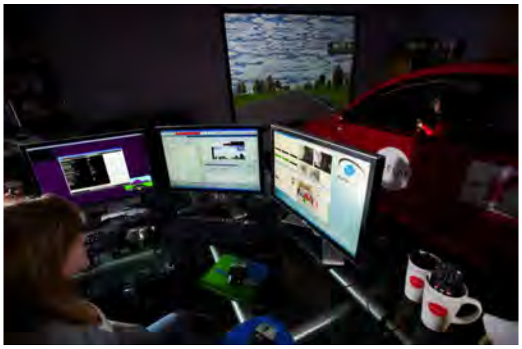

Figure 2. Driving simulation environment. The participants sit in the red car (shown in the back, right) and are instrumented with fNIRS and other physiological sensors (EKG, skin conductance). The screen in the front presents the simulated driving environment.

es are 1.5, 2, 2.5, and 3cm. Each distance measures a different depth in the cortex. Each source emits two near-infrared wavelengths (690 nm and 830 nm) to detect and differentiate between oxygenated and deoxygenated hemoglobin. The sampling rate is 6.25 Hz.

3.3 Driving Task and Secondary Task

The initial feasibility experiments will follow a protocol similar to that described in [4]. Participants will sit in the car and drive in the simulated environment. While driving, they will receive auditory prompts to perform "n-back" tasks of varying difficulty levels. In each task, a series of single-digit numbers (0-9) are presented aurally in random order. The participant must respond to each new number presentation by saying out loud the number n-positions back in the sequence. For a 0-back, the participant simply responds with the current number. At the 1-back difficulty level, they respond with the number one position back in the sequence. The more difficult 2-back requires recalling and responding with the number 2 positions back in the sequence.

4. DISCUSSION

This initial study will determine the feasibility of measuring fNIRS signals during driving tasks. Our goal in analyzing the fNIRS data will be to determine whether there are features in the signal that help to accurately classify the driver's working memory demand. We will develop analysis methods and techniques suitable for such tasks, as well as techniques for combining fNIRS with other sensors to get a more reliable classification of working memory demand. Future studies will expand this work to more realistic tasks, and to real-time assessment, if the feasibility study shows promise.

This research will allow us to examine the working memory demands of new interfaces being introduced to vehicles and could be used during design stages of such interfaces. In addition, as vehicles become more functional and autonomous, it will be increasingly important to understand the real-time cognitive state of the driver so that the vehicle can adapt to the user's state in real time.

5. ACKNOWLEDGMENTS

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In-Vehicle Natural Interaction Based on Electromyography

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ABSTRACT
In this paper, we describe a natural interface based on microgestures performed on a steering wheel and recognized through the driver's electrical muscular activity. This approach is based on a wearable paradigm of interaction, in which the sensors are placed on the user's arm. The wearable system communicates with the infotainment system of our prototype through Bluetooth. We designed the gesture vocabulary in order to facilitate the driver interaction with the infotainment system while holding the steering wheel with both hands. We tested our approach with eight users showing the possibility to recognize four microgestures with an average accuracy of 94.55%.

Categories and Subject Descriptors
H [**Information Systems**]: H.5 Information Interfaces and Presentation—*H.5.2 User Interfaces;*

General Terms
Experimentation, Human Factors.

Keywords
Electromyography; Microgestures; In-Vehicle Interaction.

1. INTRODUCTION
Nowadays, In-Vehicle Information and communication Systems (IVISs) provide increasing entertainment and communication opportunities while driving. Most IVISs are placed in the central console of the car, allowing both driver and passenger to control it. Unfortunately, these systems may distract the driver, which has to shift the eye gaze and attention from the road and to move one hand from the steering wheel. In fact, many IVISs include buttons around a central display as well as multifunctional controllers or touch displays for controlling secondary tasks. The result of this approach consists in the user being overwhelmed by a plethora of controllers on his/her dashboard. The impact on the driving task of such IVIS has been studied by Bach et al. and compared to a gestural interface in [1]. The research community agrees on considering the gestural interaction for the driver as safer than using controllers that are distributed on the dashboard. Indeed, Riener stated that "in-vehicle gestural interfaces are easy to use and increase safety by reducing visual demand on the driver" [6]. Similarly, Döring et al. assessed that the driver's visual demand is reduced significantly by using gestural interaction on the multi-touch steering wheel that they developed and presented in [4].

The main contribution of this work is a natural interface based on microgestures focusing on the driver interaction with an IVIS. This system adopts the wearable paradigm that consists in placing the sensors on the user. These sensors capture the electromyographic (EMG) signals generated by the electrical muscles activity. The wearable system sends these data to the IVIS. Finally, the IVIS interprets these data as commands. In the next section we describe the system architecture, the gestures design with relative anatomic details for the sensors placement and the first tests we conducted in order to validate this approach.

2. APPROACH
Developing an interface to interact with the IVIS of a car typically requires integrating physical interfaces in the vehicle. This can be problematic since a change in the hardware involves a significant modification in the production chain of a car. In this paper, we propose an approach based on a wearable paradigm, which has the advantage of separating the technology on the user and the technology on the car. The onboard system has to receive and interpret the signals from the wearable component. Acquiring data from wearable sensors, the interaction can be done on the entire surface of the steering wheel external ring.

Designing our gesture vocabulary (see Figure 1), we limit our research on interactions that are not demanding for the driver. The interface should not distract the user from his/her primary task: driving. In addition, we chose to focus on gestures supporting the driver interaction even while holding the steering wheel with both hands. For instance, the driver can control the IVIS without moving the gaze from the road conserving the safety of the driving.

Microgestures, if correctly designed, allow executing a secondary task without interrupting or interfering with the primary task. Wolf et al. [7] studied the design of gestures in a car having the driving as primary task. The authors proposed a list of optimal microgestures in terms of feasibility, attention and risk of confusion. Extending their research, we defined the simple microgestures vocabulary depicted in Figure 1.

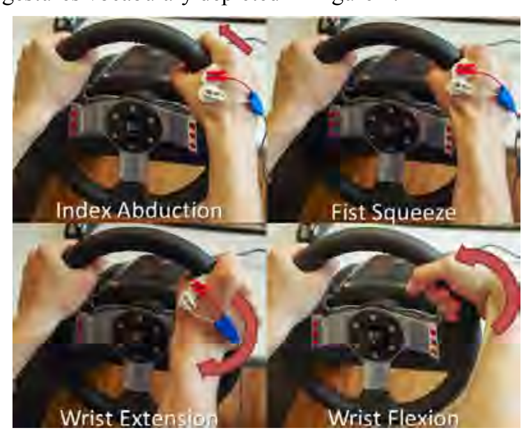

Figure 1. The four gestures used for the interaction.

Figure 1 presents the lexicon of four microgestures that we have adopted in our study: a) index abduction, b) fist squeeze, c) wrist extension and d) wrist flexion.

This lexicon can be extended to other gestures. The presented microgestures have been chosen to validate different typologies. Indeed, the index abduction represents a category of microgestures performed with the fingers that are easy to detect with sensors on the dorsum (back) of the hand. The wrist extension and flexion gestures validate the possibility of interaction sliding on the steering wheel. Finally, the fist squeeze belongs to the category of the "motionless" gestures. We limited the vocabulary to four microgestures in order to reduce the cognitive load and make the interaction safer.

3. SYSTEM OVERVIEW

The system senses the electrical activity of four muscles: the *First Dorsal Interosseous*, the *Flexor Carpi Ulnaris*, the *Palmaris Longus* and the *Extensor Digitorum*. Figure 2 shows the signals of every sensed muscle for each microgesture. The four channels are sensed by a wireless EMG device [5] that amplifies and sends the information to a processing unit for the feature extraction. We used the following features: signals Root Mean Square, Logarithmic Band Power and Mean Absolute Value. The system processes these signals in temporal windows of 256 ms with an overlapping of 128 ms. Afterwards, signals are stored to train four Linear Discriminant Analysis classifiers (one for each microgesture).

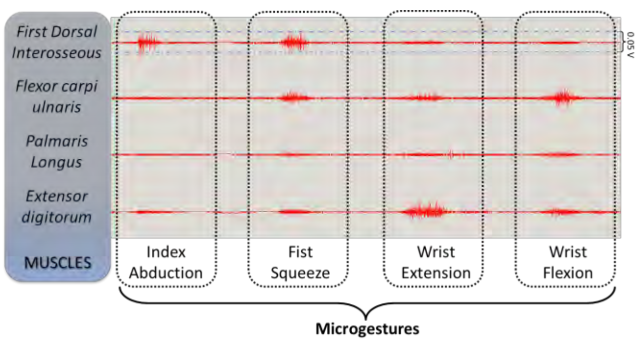

Figure 2. EMG signals of every sensed muscle for each microgesture.

4. SYSTEM EVALUATION

4.1 Protocol of Interaction

Eight people, aged within 23 and 31 years took part to the experiment. None of our participants had any known neuromuscular diseases. Sensors were positioned by non-medical personal following Cram's guide [3].

The experiment was composed by two identical sessions of 3 minutes. Each participant had to perform on a steering wheel 10 times the four microgestures, for a total over the two sessions of 80 gestures. Visual external stimuli led the participants through the experiment suggesting the gesture to perform.

4.2 Results and Discussion

In order to evaluate the system performance, we performed a k-fold cross-validation ($k = 10$) resulting in an average accuracy of 94.55% and a standard deviation of 3.77.

Each microgesture obtained a similar recognition accuracy rate: 92.98% the index abduction, 94.38% the fist squeeze, 95.51% the wrist extension and 95.34% the wrist flexion.

These results are very encouraging; however, further tests with a gesture segmentation system are required for real world scenarios. Moreover, in order to complete the evaluation, we need a test with more participants taking into account also the usability aspects.

5. CONCLUSION

IVISs are becoming more and more complex, providing increasing services but overwhelming the driver with buttons and knobs. Human-computer interaction researchers working in the automotive field identified a promising solution in the gestural interfaces. Indeed, we proposed an interface based on four microgestures performed with both hands holding the steering wheel. The system we developed is composed of a wearable device that captures the driver's EMG signals and of an IVIS that receives these data. The IVIS interprets these data in order to recognize the performed microgestures and to activate the related commands. We conducted a test in order to evaluate the accuracy of the developed system for the proposed microgestures recognition. The results assessed an average accuracy of 94.55% with a standard deviation of 3.77.

The future steps of this research consist in integrating an EMG-based gesture segmentation system (we realized a preliminary study presented in [2]), conducting tests during simulated driving activity and integrating such IVIS in a real vehicle for further testing.

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Driving Infotainment App: Gamification of Performance Driving

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ABSTRACT
Infotainment apps are software that combines information and entertainment. This paper explores the use of gamification and performance driving as design elements of an infotainment app that can transform the boring and mundane aspects of drives into productive, entertaining, engaging, and fun experiences. The app is a performance driving game called „Driving Miss Daisy‟ [6]. The game can be played either repeatedly on daily routines or casually on one trip. Aside from the education and productive elements, the game is designed to entertain and engage.

Categories and Subject Descriptors
H.5.2. [**Information interfaces and presentation**]: User Interfaces; K.8.0 [**Personal Computing**]: Games.

General Terms
Design, Human Factors.

Keywords
Experience, gamification, in-vehicle infotainment, performance driving, skill mastery.

1. INTRODUCTION
Automobile manufacturers are exploring in-vehicle ways to make the journey less boring. One approach is to translate information about physical driving parameters into vivid animation. For example, the Chevrolet Volt‟s „Driver Information Center‟ displays a ball that animates and changes color (e.g., yellow for sudden braking) based on a car‟s acceleration or deceleration [5]. Information media that make an intentional effort to entertain are known as infotainment apps.

As a driving task, performance driving shares similar task and situational characteristics with routine driving. Thus, performance driving can provide the informational component for an infotainment app for routine drives. When combined with gamification [4], we have the entertainment component for the app. Tying entertainment to the informational presentation of the driver‟s performance can offer two benefits to the driver: a) relieve the tedium of driving and b) give real-time feedback of how well the driver is driving. This paper explores a novel way of entertaining drivers during routine drives by designing a performance driving competition game that uses the routine drives as the game context.

2. GAME MODE AND FLOW
The game, named „Driving Miss Daisy‟, has two competing modes. A player can compete with all the other players who have traveled the same route (defined as sharing the same starting and end points) within the past week. We call this mode „public competition‟. In addition, a player can compete with herself if she has been driving on the same route routinely. We call this mode „self competition‟. The „public competition‟ mode is turned on by default while the „self competition‟ mode will be turned on automatically if the app detects a route is repeated.

When the game is launched, it chooses the game level for the players based on their previous performance. For a new player, the game begins with the „easy‟ level that sets a higher triggering threshold for bad driving behavior and a lower triggering threshold for good driving behavior. The goal for the player is to drive a virtual passenger, Miss Daisy, to the destination safely and smoothly and to avoid hazardous and uncomfortable maneuvers like sudden braking (see Figure 1).When a drive ends, the player is given a summary of her trip and performance. In addition to driving statistics, the summary also tells the player how she competes herself in the past („self competition‟ mode) or other players („public competition‟ mode). (See Figure 2).

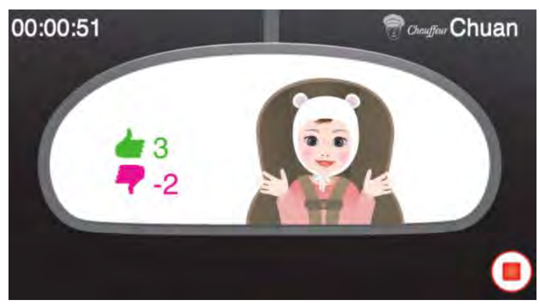

Figure 1. Driving Miss Daisy display.

Figure 2. Game summary presented at end of drive.

3. OUR GOALS

The design of the game app has three main goals. First, the game makes drives fun, entertaining and engaging experiences. Second, the game is focused on developing car control skills and therefore drivers should not be less cautious in driving due to playing our game. Third, the bonus aspect of the game is that it turns drives into productive and educational experiences where drivers can improve their driving performances.

4. GAME DESIGN

To achieve the goal of being entertaining, the app uses several game design strategies. First, the game is a role-playing game. Our game‟s back story is inspired by the movie „Driving Miss Daisy‟ [6]. Miss Daisy is a virtual passenger and the player is the driver and her chauffeur. She occasionally comments on the chauffeur‟s real and actual driving performance. Audio feedback is primarily used so that drivers do not need to constantly attend to the display [2]. Our Miss Daisy is a young girl to make the character and the audio effect cute and playful. Different audio feedback snippets are mapped to each action for variety. More generally, our design envisions different persona for Miss Daisy; each persona offers different ways to entertain and models different feedback caricatures.

Second, reward mechanisms are incorporated to motivate user engagement. The game monitors smooth and hazardous driving performance. Smooth driving performance includes constant driving speed for a period of time (aka cruise control), driving within speed limit, smooth acceleration and deceleration of the vehicle, and smooth cornering. Hazardous driving includes going over the speed limit, sudden starts and stops, sharp cornering, and erratic lane changes. Our initial prototype implements all but the cornering and lane changes. For detected driving performance, players will receive thumbs-up and thumbs-down, accumulate game score, and earn “virtual money” on each drive. The three types of rewards play different roles in motivating participation. The thumbs-up and thumbs-down counts are shown to players as they drive, since it is the most direct and immediate way of giving feedback of driving performance. The game score is the weighted sum of smooth and hazardous driving incidences that help players understand differences in potential risk of hazardous maneuvers and the difficulty of performing smooth behaviors; thus making the game more realistic. “Virtual money” is accumulated over multiple rounds of game play with the initial balance being 0 for first-time players. It is a long-term measurement that is used to cultivate loyalty to the game.

Third, competition is added to increase fun and engagement for players. More importantly, the game promotes good car-control skills over different road conditions including traffic and discourages the driver‟s bad driving behaviors. Players are able to compete with themselves by comparing performances over the same route on different days or compete with others through the reporting of their rank among all people that have played the game on the same route (see Figure 2).

5. IMPLEMENTATION DETAILS

The app collects driving data such as car speed from OBD, accelerometer readings from the smartphone, altitude from smartphone‟s GPS, and speed limit of the current road from Nokia‟s maps API service [7]. It analyzes the data in real-time to identify periods of good and bad driving performance. Game rules are designed to motivate the player to drive their vehicle with high performance. Our initial prototype does not account for traffic but we intend to incorporate traffic information and to adjust the thresholds based on heavy and light traffic [7, 8].

The game is a HTML5 application that runs inside a Web browser on the smartphone. As the app involves mash-up of data and functionality from the smartphone, the car, and the cloud, HTML5 is a natural programming paradigm for the app. The app accesses driving data from the car‟s on-board diagnostics (OBD) and smartphone‟s sensors. The prevalence of sensor-packed smartphones and their co-presence in cars because of their owners make smartphones a natural platform to deliver infotainment apps. Car speed from OBD is accessed through a Javascript API that is implemented as a browser plugin. Altitude and accelerometer data are accessed via local Web services provided by the smartphone. Nokia‟s Map APIs provide, for example, cloud services for speed limit and traffic information. Finally, the phone is connected to a MirrorLink-enabled head unit via USB. We use MirrorLink [1, 3] technology to deliver the browser-based application running on the smartphone to a car‟s dashboard. Drivers can leverage the head unit‟s larger screen and interact directly with the head unit‟s touchscreen, which is safer and easier to use.

6. SUMMARY AND NEXT STEPS

Our game uses game techniques to entertain drivers while minimizing distraction. Our next steps include extending the game with different persona and features mentioned earlier (e.g., cornering, lane changes, traffic) that form the basis of our overall design. As well, we plan to conduct user study to obtain user feedback concerning our assumptions: 1) drivers feel „entertained‟ playing our game; 2) drivers are not distracted and operate vehicles with more caution when playing our game, and 3) drivers improve on their performance driving skills as a result of playing the game during routine drives.

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Effects of Audio Cues for a Song Searching Task on Cell Phone While Driving

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ABSTRACT
Driving distraction is a vital issue within driving research. This paper discusses ongoing research in applying auditory cues to enhance song-searching abilities on a portable music player or smartphone while driving. Previous research related to this area has revealed issues with using these devices while driving but some research has shown significant benefits in using audio cues.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces And Presentation (e.g., HCI)**]: User Interfaces – Auditory (non-speech) feedback, graphical user interfaces (GUI), interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design, voice I/O

H.5.1 [**Information Interfaces And Presentation (e.g., HCI)**]: Multimedia Information Systems – audio input/output

General Terms
Design, Experimentation, Human Factors, Performance.

Keywords
Audio cues; Driving; Lane change task; In-vehicle technologies

1. INTRODUCTION
Driver distraction is a critical issue within the modern driving world, with large amounts of research (and press) reporting decreases in driving performance when drivers take part in other (distracting) tasks. Some of the more prevalent studies investigate the detrimental impact of activities such as texting [1] or talking on a cell phone [2]. However, relative to time in the car, these are not necessarily the most often performed actions that can cause distraction. One topic that is often ignored is that of driving and list selection, such as finding a song on a phone or mp3 device.

2. DRIVING AND MP3
Smartphones and mp3 players' prevalence has increased in the past years and accordingly their use and popularity within the vehicle has increased as well. However, compared to in-vehicle radio systems, smartphones and mp3 players were not designed with driving as a primary task in mind. Some recent research has investigated the use of these handheld devices for song selection while driving [3][4]. A simulator study showed a significant decrease in visual attention on the driving task as well as decreases in driving performance [3]. While these studies have investigated the results of driving while finding songs, little research has been done investigating how to remedy this issue.

3. ADDING AUDITORY CUES
Auditory cues have been shown to be useful in a menu search task, specifically cues such as spindex and spearcons (for a full explanation on these cues see [5]). These sorts of cues could be applied to the mp3 search task in an effort to decrease visual demands on the driver, thereby reducing the negative impact on driving. According to multiple resource theory [6] by giving the cues through audition, visual demand would not be as tasked, therefore leaving more visual resources to be applied towards the primary driving task. Our own previous research applying these cues within the driving context has shown promising results in multiple settings, including finding songs on a in-vehicle infotainment system (a "head unit") [7], and a driving task in a mid-fidelity simulator [8].

4. PRESENT STUDY
The present work in progress is investigating the cognitive, performance, and visual effects on driving while performing a secondary menu search task on a smartphone, with or without auditory cues.

4.1 Method

4.1.1 Participants
The sample of participants will be composed of undergrad psychology majors. They will receive extra credit in one of their courses for participating in the study.

4.1.2 Apparatus
The primary task of driving will be the Daimler Chrysler Lane Change Task (LCT) and will help to measure distraction and driving performance. The task will be performed using a Logitech steering wheel and pedal, and displayed on an LG TV and audio presented through Dell A215 desktop speakers. The secondary task of the search task will be performed on a Google Nexus One HTC1 Android smartphone running version 2.3.6. The application used for this song-finding task will be similar to the "flicking" block of trials in [4], including the same list of 150 songs. This flicking technique was chosen since the majority of smartphones and mp3 devices currently employ this method of interaction. A

Figure 1. An individual performing the primary driving task and secondary task of navigation a list of songs.

few modifications were made on the application however, including auditory presentation of the search request and a four second break between each request. These auditory stimuli and the cues used during the searching will be presented on Dell A215 desktop speakers. Participants will also wear Tobii eye-tracking glasses (see Figure 1), to investigate visual attention. Questionnaires used in the study will include the NASA Task Load Index (TLX) to measure cognitive load, Edinburgh Handedness Test, a preference questionnaire to compare which auditory cues were preferred, and a demographics questionnaire.

4.1.3 Procedure

Participants will complete consent forms, and receive a short description of the tasks. Participants will complete the Edinburgh Handedness Test, followed by fitting and calibration of the Tobii eye-trackers. They will then perform a short practice drive on the LCT to allow them to become familiar with the task.

Participants will then begin the testing blocks, during which they will hold the cell phone in their choice of one hands, with arm resting on the armrest of the chair throughout the study. They will interact with the phone during the testing blocks with just one hand while the other will be on the steering wheel. During any block where interaction with the phone is not needed, participants will still have the cell phone in their hand. The six testing blocks will be randomized across participants and will include: Search task no sound, search task with text to speech (TTS), search task with spindex and TTS, search task with spearcon and TTS, search task with spindex spearcon and TTS, and no search task. Each of the testing blocks consists of the introduction to the current type of auditory cue followed by a short practice with that version of the cue. They will then drive one length of the LCT, which consists of 18 signs and lane changes. Each participant will complete every possible lane change (i.e. left to center, right to left, etc.) with order randomized. Immediately after each drive participants will perform the NASA TLX followed by a rating form regarding those auditory cues. After completing the six conditions participants will be asked to fill out the short demographics survey followed by a debriefing.

The driving data will be analyzed using the LCT analysis software and eye-tracking data will be tallied for when participants were viewing the primary or secondary task. The number of songs a participant finds during the driving task will also be tallied and NASA TLX scores as well as preferences will be compared.

5. EXPECTED RESULTS

It is expected that a significant increase in cognitive load, phone viewing time, and variance within the Lane Change Task (LCT) will be observed when drivers perform the search task with no auditory cues, as compared to a baseline where no search task is completed. Once auditory cues are applied within the search task it is expected that the cognitive load, phone viewing time, and variance in the LCT will decrease. Based on previous work [8], it is expected that the Spindex and Spearcon conditions will show the highest performance increase within the auditory cues as compared to no auditory. It is also expected that the number of songs found and selected during the drive will be higher during the trials with auditory cues.

6. IMPLICATIONS

Implications gained from this study could be highly applicable to decrease driver distraction in real driving. If the expected results do occur then it will provide further evidence that the application of auditory cues, specifically these types of auditory cues, can decrease the distraction in driving and searching on lists, whether it be songs, contacts, or other items on an electronic device.

7. ACKNOWLEDGMENTS

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Simulator-based Evaluation on the Impact of Visual Complexity and Speed on Driver's Cognitive Load

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ABSTRACT
Assessing the driver's cognitive load has become an increasing research interest. Methods described in literature fall into three categories: self-assessment, physiological measures, and performance-based measures. We claim that cognitive load can also be deducted by environmental factors, such as visual complexity of the context or driving speed. This paper describes an experiment aimed at backing this claim and its first results.

Categories and Subject Descriptors
H.5 [**Information Interfaces and Applications**]: User Interfaces; H1.2 [**User/Machine Systems**]: Human factors—*complexity measures, performance measures*

General Terms
Theory

Keywords
cognitive load, presentation complexity, automotive information systems

1. INTRODUCTION
We claim that environmental factors correlate with the driving performance, e.g. reaction time, and thus also serve as an indicator for the current cognitive load of the driver. Now, we attempt to back this hypothesis with empirical data acquired in a driving simulator test.

Real-life field studies for evaluating driver distraction are often inefficient (e.g. observing accident data) or intricate to accomplish. On the other hand, indirect laboratory methods measuring reaction times independent of the real driving context can be of limited validity. To overcome these shortcomings, [3] introduced the Lane Change Test (LCT) as a measure of the influence of the secondary task on the driving performance in a simple simulator task.
The original LCT consists of a simple driving simulation at a regular consumer PC with steering wheel and foot pedals used for computer games. The subject is driving on a straigh three-lane road with traffic signs indicating which lane to use.These traffic signs are used as stimuli, and the corresponding maneuver of the driver is the response. In between two responses, the subject still has to keep driving and stay on his current lane.
The LCT was subsequentially standardized as an ISO norm in 2008 [2].

The LCT Kit as an implementation is developed since 2009 at the Leibniz Research Centre for Working Environment and Human Factors (IfADo), based on the original Lane Change Test. Its main purpose is to determine reaction times and also the connection between driver reaction times and the placement of the stimulus in the left or right visual half-field, such as [1].
In this simulation, the driver is placed in the middle lane of a straight road with a screen-filling number of lanes to the left and right. Except for seeing his own car interior, there are no visual distractions in the simulation. After a prompt, a short instruction to change lanes (either one or two lanes to left or right) is displayed for 300 milliseconds on one side of the screen. This short time span is sufficiently long to decode the information after a short training but short enough to avoid saccades, which would add noise to the data to be observed. The reaction to the stimulus is measured as the time span between stimulus and a steering wheel angle outside of the ordinary lane keeping range. Furthermore, the task of changing the lane has to be completed in a certain amount of time.

OpenDS[1] is an open source driving simulator software developped in our automotive group at the German Research Center for Artificial Intelligence. It is based completely on open source modules.
OpenDS was developped with the intention to have a flexible driving simulation, which can perform the standard Lane Change Test (LCT), but easily extended to other/similar/new testing tools beyond the possibilities of LCT, since the original LCT is very restricted and not extendable.

2. EXPERIMENT
The experiment described here is based on the IfADo LCT Kit (see figure 1). We reimplemented the task in OpenDS and made some modifications: As the aim is to show the correlation between contextual complexity and cognitive load,

[1]www.gethomesafe-fp7.eu/index.php/menu-opends

AutomotiveUI'12, October 17-19, Portsmouth, NH, USA.
Adjunct Proceedings

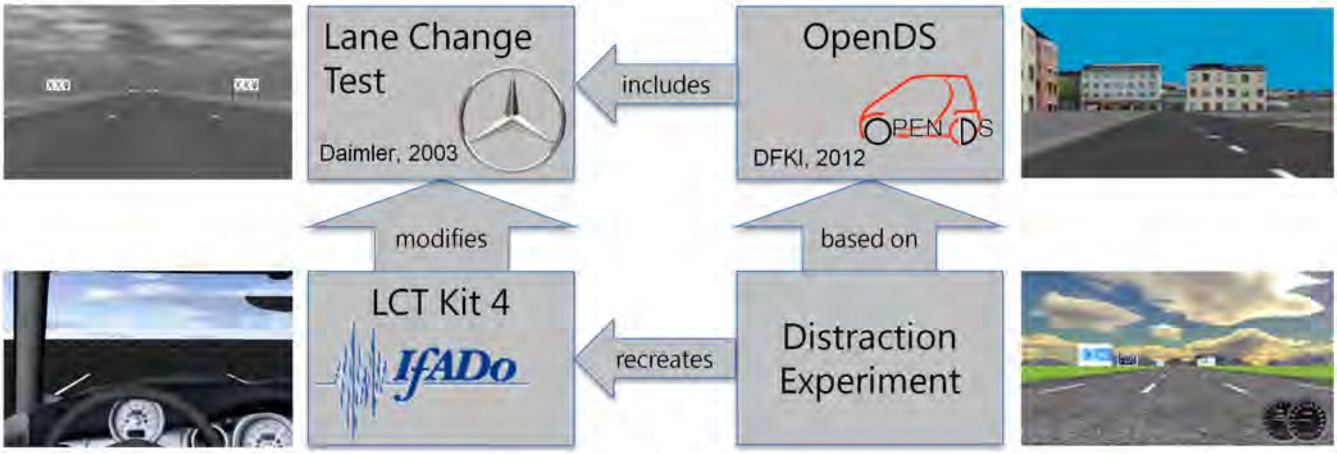

Figure 1: The distraction experiment described here is a reimplementation of the LCT Kit in our OpenDS driving simulator. It is based on the Lane Change Test, but measures reaction time instead of lane deviation.

we change the parameters speed and visual complexity.

Visual complexity
The original experiment uses infinite lanes and offers no visual distraction for the subject. In a first step, we reduce the number of lanes to a necessary minimum of five and fill the remainder of the visible plane with monochrome shading. To avoid predictability (e.g. the subject knows the next instruction must be left because she is on the far right lane), the driver is automatically centered again on the middle of 5 lanes by adding or removing lanes on the respective sides. Now, we introduce visual complexity by adding objects (billboards) to both sides of the street. To keep different experiment runs comparable, all objects are of same size and similar visual complexity, i.e. identical models. The hypothesis to be verified in the experiment is a positive correlation between visible objects in the subjects viewfield and the reaction time during the experiment.

Vehicle speed
The second assumption to be verified here is the correlation between vehicle speed and reaction time. We extend the original experiment and run it in different speeds. This assumption is closely related to the previous assumption, as the higher vehicle speed results in faster change in the visually perceived environment.

In a pre-test before the main study, five subjects drove in the simulation under varying conditions. Their task was to react as fast as possible to lane change commands displayed on the screen. We used three variants of visual complexity (no distractions, some billboards on the side of the road, many billboards on the side of the road) and two different speeds (60-80 km/h and 120-140 km/h). In order to observe whether or not any training effect in getting used to our simulator occurred, three of the subjects were asked to perform the test twice in a row.
As setup, we used a real car positioned in front of three projection walls covering a visual range of 120 degrees.

3. RESULTS

Results of the pre-test clearly confirmed our two hypotheses: (1) The average reaction time increases with increasing speed. (2) The average reaction time increases with the number of distracting objects (billboards) on the roadside. A more detailed look at the data is shown in table 1.
An interesting effect can be found when looking at the reaction time under both varying speed as well as varying number of distractions: While in average and at high speed the reaction time increases with the number of distractions, the exact opposite can be observed at slow speed. Our first assumption that this can be attributed to training could not be confirmed, since the effect prevailed when only considering the three test runs of subjects performing the test for a second time. We will provide more detailed results after the main study on the conference.

	slow driving	fast driving
no distraction	1380 ms	1387 ms
medium distraction	1344 ms	1464 ms
high distraction	1126 ms	1783 ms

Table 1: Average reaction time in ms under varying conditions

4. ACKNOWLEDGMENTS

We would like to thank our colleagues from training science for collaboration and support, especially Professor Stefan Panzer and Peter Leinen.

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Towards a Simple City Driving Simulator Based on Speed Dreams and OSM

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ABSTRACT

This paper presents an architecture and partially built simulation platform which is designed to offer a flexible open ended approach for conducting laboratory experiments. The emphasis is on supporting multiple drivers and the ability to swap in and out different software components and devices.

Categories and Subject Descriptors

J.4 [**Social and Behavioral Sciences**]: Sociology, Psychology; D.2.2 [**Software Engineering**]: Design Tools and Techniques—*User interfaces*

Keywords

City driving simulator, OSM, Speed Dreams, Usability

1. INTRODUCTION

The City of Luxembourg is the 10th most congested city in Europe [9]. In order to overcome this problem, the I-GEAR project was created and it specifically explores how we can encourage commuters to subtly change their mobility behaviour through the use of game-like mobile applications. The project has two key testing stages that explore these issues which need a specific simulation environment.

A key requirement is that the simulator must be highly modular and customisable, for example, supporting new graphical engines as they become available, large city-like environments with complex layouts, having more than one driver at any given time and finally also allowing us to change/modify and remove hardware components such as tablet PCs at short notice. We chose not to buy a commercial platform as these are often heavily locked down and are too expensive when multiple cockpits are required. As a result we chose to base our simulator on an architecture of open source components coupled with a robust underlying highly flexible server application. This approach allows us for example to completely change the 3D environment with minimal impact on other aspects and to use the programming languages of our choice for controlling the simulation environment.

2. SIMULATOR

For the 3D environment we are using Speed Dreams (SD) [7] which is an open source motor sport simulator which is forked from the Torcs platform [8]. The platform supports a range of cars, standard driving controls (e.g. pedals) and is edging slowly towards providing networked game play with multiple drivers. It is written in C++, runs on Linux, Windows and soon Mac OS X and is easily customisable.

2.1 Speed Dreams track model

SD is focused on supporting motor racing and each track consists of a sequence of segments such that the end of the last segment coincides with the beginning of the first to form a lap. A segment may be given a curvature radius, a tilt and also may have different starting and ending widths and altitudes. This track information is stored in an XML file. A car can move only inside the track limited with the barriers. Any other objects, like trees or buildings, have no impact with the car, and they are usually placed outside the track.

2.2 Problems Encountered

In order to use SD for our purposes, we had to solve a couple of problems:

- Road intersections are not foreseen, while these are a common case for city road-maps (a workaround is described in Section 2.3).
- There is no 3D scene of Luxembourg city integrated in the simulator (see Section 3).
- There is no traffic. Moreover, SD robots rely on xml description of the track (not yet addressed).
- There are no traffic lights (not yet addressed).

2.3 Source code adaptation

As mentioned above, SD could *not* be used *as it is* for city driving due to impossibility of defining road intersections. Thus, we introduced some changes in the source code based on the following idea. If we ensure that the track describes a flat world (i.e. the track has a constant altitude) and disable the collision test with the barriers, then the car can drive to any point of the scene. Then, if a driver will not go off the road[1] which he/she sees as a part of 3D scene, we obtain a solution: one can drive on an arbitrary road-map ignoring the track information.

Another change we applied is an integration of telemetry data transmission via TCP (see Section 4).

[1]Since we disabled the collision detection with barriers, we also have to implement it with using objects in the 3D model

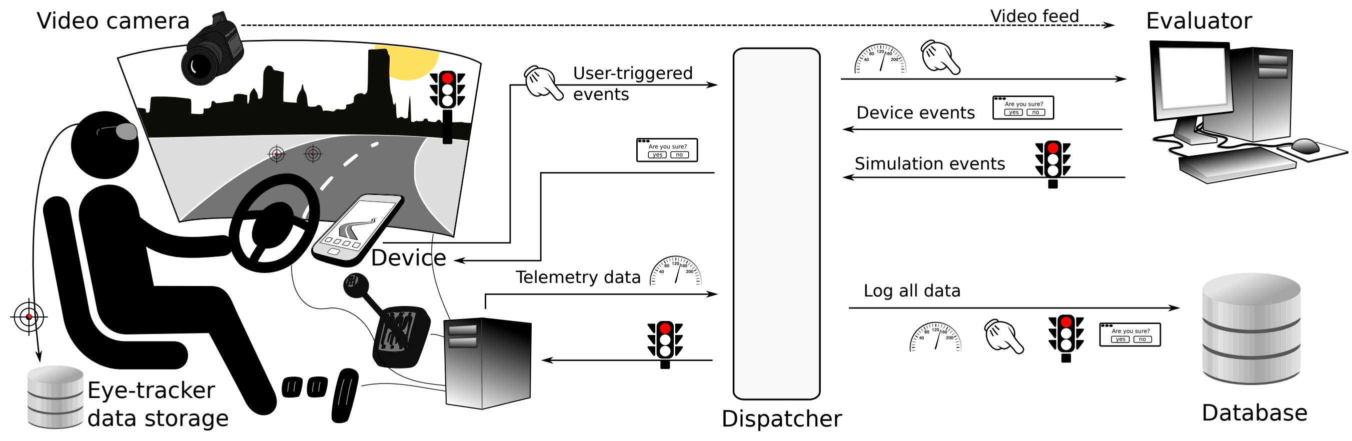

Figure 1: A scheme of the simulator usage in I-GEAR

3. 3D CITY MODEL

SD uses AC3D format [1] to describe 3D scene. While this is flexible, building a 3D model of Luxembourg City is a complex task and in order to speed up the process we used data from OpenStreetMaps [10] (OSM) and it's satellite projects.

First, we had to crop the OSM country description to reflect our area of interest (Luxembourg City). The tools [6] and [5] provide such functionality by taking as input an OSM data file and a polygon description of the desired area. The latter can be created in [3] by selecting the desired area on a the map. *Second*, we used OSM2World [4] to create an initial 3D scene of the area which then exported to a Wavefront `.obj` file. *Third*, we imported the .obj file into Blender [2], a 3D open content creation suite, where the scene can be edited (e.g. by adding building facade textures) and using 3rd party scripts, the result was then exported to AC3D formatted file (`.ac`). *Finally*, the `.ac` file can be used by SD.

We note that some objects generated by OSM2World have a relatively high number of polygons which in turn causes performance issues (if not SD crashes) during the simulation. That is why we had to replace some objects with lower polygon counts. This was carried out by editing the scene in Blender, however we plan to use OSM2World.

4. EVALUATION ENVIRONMENT

Our primary focus within the simulator is to observe driver behaviour and to log their actions. We plan to log various data relevant to driver's behaviour, vehicle and in-car devices. In order to achieve this objective we have outlined the core components in the following section and in Figure 1.

Evaluator PC acts as control centre for the evaluator and displays the current telemetry data, status of the device and provides live video feeds of the driver and 3D model. Additionally it supports setting up and controlling each experiment as well as triggering events both in the 3D model (e.g. switching traffic lights) and on devices like tablet PCs.

Video camera A video feed of the drivers cockpit including the 3D model and controls.

Eye tracker An SMI head-mounted mobile eye tracker is used to track the drivers gaze position, dwell time and eye movements.

Device Any in-vehicle device that is used for capturing and displaying data (smartphone, tablet PC, etc.).

Database Data from the simulation is logged in SQLite database. Can be easily switched to any other DBMS.

Dispatcher Dispatches the data flow as shown in the Figure 1. We implemented it in Python.

As for communication protocol we use JSON. Telemetry data contains current speed, acceleration, car position, controllers status etc. Every user action on a device is logged and sent to the dispatcher. All this data is stored in the database and can be analysed later on.

5. CONCLUSIONS

We have presented an overview of the I-GEAR simulator environment which will be used for the analysis of driving patterns and human-factors issues. Among the key benefits of our approach are: the relative low cost, support for multiple drivers, high modularity and the ability to support any part of the world through the use of Open Street Map.

6. ACKNOWLEDGMENTS

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Speech Dialog Generation from Graphical UIs of Nomadic Devices and the Integration into an Automotive HMI

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ABSTRACT

More and more people use smartphones regularly for various tasks. Due to distraction issues, the usage is prohibited while driving and thus an integration into the automotive HMI is needed. As speech interaction distracts less than visual/haptic interaction, the smartphone integration needs to support the speech interaction concept of the automotive infotainment system. This paper presents a method to generate the lexicon, grammar, and dialog flow for the car's Speech Dialog System (SDS) based on the GUI specification of smartphone applications. Our approach is platform-independent and application-independent, provides consistent dialogs for all smartphone apps, and complies with the car's interaction paradigm.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*GUI; Natural language; Voice I/O*

Keywords

Modality translation, multimodal software development, synonym phrases, task-based interaction

1. MOTIVATION

Nowadays, people would like to use nomadic devices even while driving. Therefore, automotive HMIs provide connections to phones, mp3 players, and smartphones. However, only the basic functionality of these devices is available in the HMI and people tend to use smartphones despite it is prohibited and dangerous. Many solutions evolved which integrate the smartphone's UI in the automotive HMI and allow a visual/haptic interaction (e.g. MirrorLink[1]). However, voice control is neglected. On smartphones, there are applications (apps) which support voice control (e.g. Apple's Siri). They could be used and integrated into the automotive HMI. However, not all functions can be controlled by voice - especially, third party apps are neglected.

In general, to develop a multimodal app two approaches are common: specifying each modality or defining the UI with modality-independent models. Manual specification for multiple modalities is time-consuming and model-based development requires special knowledge by the developer. Furthermore, for apps on smartphones the visual/haptic modality works fine but from the developer's point of view it does not pay off to provide multiple modalities. As a result, the speech modality is missing by integrating the smartphone into an automotive HMI. Adding this manually is not possible due to the quantity and open application scope of third-party apps.

So far, no domain-independent integration of nomadic devices into an automotive HMI considering speech modality exists. To resolve this and allow voice control of smartphone apps, this paper shows work-in-progress to extract user tasks from the GUI and to generate speech dialogs based on the tasks. As GUIs of smartphones overlap with websites to some extend, [2, 6, 3] form a basis for our work.

2. TRANSLATION FROM VISUAL/HAPTIC MODALITY TO SPEECH MODALITY

In the development process of an app the developer considers the user's tasks as well as the app's functions and creates a UI providing the interaction possibilities. On a smartphone the UI consists of various GUI widgets which are assembled logically in a hierarchical structure. Each of the widgets has specific functions which support the users to complete their tasks. We analyze the elements on the GUI in terms of attributes, affordances, and relationships to each other to derive from the elements a set of tasks the user can perform with the GUI. We use the tasks to translate the visual/haptic modality into speech dialogs. As each modality requires an adaptation of interaction elements to supply an efficient usability [4], we have chosen to first abstract the GUI to task level and second reify the tasks to speech dialogs (see Figure 1). This process complies with the CAMELEON Reference Framework (CRF)[1].

The abstract GUI elements are based on Simon et al.'s classification [5], however, are refined by considering the user tasks. This results in the abstract GUI elements: information, multimedia, state, action, input, and structure. Each platform-dependent GUI widget can be abstracted with these types. In the first step of the translation a platform-dependent GUI description (Android XML) is abstracted to User Interface Markup Language (UIML). The UIML file contains the assembling of the GUI in abstract GUI elements including important attributes like size, color, emphasis, grammar, and ontology. For example, a TimePicker (widget for selecting the time of day) in Android is abstracted to an input element referencing the time ontology. Each abstract ele-

[1] `http://terminalmode.org/`

Figure 1: Translation steps from visual/haptic modality to speech modality

Figure 2: Semantic of TextField is defined by Label (Screenshot)

ment stands for various tasks. For example, an input element allows the insertion of text and presents the inserted text to the user. Furthermore, for each task meta speech dialogs are specified which allow task execution by speech. In summary, the GUI is translated into meta speech dialogs which are instantiated with application data at runtime.

3. INSTANTIATION OF SPEECH DIALOGS WITH DYNAMIC DATA FROM APPS

The meta speech dialogs are instantiated with data from the corresponding GUI element on the smartphone. Based on this, vocabulary and grammar for the SDS are generated. The grammar includes in each phrase a user task and its semantic GUI reference. The semantic GUI reference is the element users associate with the task. The abstract GUI element which can fulfill the user's task differs from the one providing the semantic information. Considering the Western Culture with reading direction from left-to-right and top-to-bottom, a GUI element sets the semantic for its following ones. For example, in Figure 2 the Label's description ("Next Meeting") assigns the semantic for the following input elements ("2012/10/17" and "Portsmouth"). Our matching algorithm processes a UIML GUI description and identifies a GUI element which can fulfill the user's task based on the element providing the semantic information. An example phrase for the GUI in Figure 2 is: "Set *Next Meeting* to *2012/10/17*".

So far, only runtime values and meta phrases are considered which result in an enhanced "say-what-you-see" system. In natural language different phrases can have the same meaning (synonym phrases). We address this by assigning ontologies to abstract GUI elements and thus allow activation of special grammars (e.g. time grammars). For dynamic data, which is not known until runtime, we use pattern matching to determine the ontology. Furthermore, a thesaurus looks up synonyms. These methods are combined to generate various synonym phrases for each original phrase and are added to the SDS's lexicon. A synonym phrase for the GUI in Figure 2 is: "Set *Next Conference* to *Wednesday*".

Keeping dialogs short, the output depends on the importance of the GUI element providing the data. The user is primarily interested in the most important fact and thus this is read out. Less important information can be accessed by explicit request. The significance of a GUI element is calculated based on its appearance, namely size, color, and emphasis. This means in Figure 2 the bold *2012/10/17* is more important than *Portsmouth*, which results in the dialog: "What is the content of *Next Meeting*?" - "2012/10/17".

4. EVALUATION

For evaluation purpose, we implemented our algorithms in a prototype based on Android and the Daimler's SDS (the SDS provides speech understanding, dialog handling, TTS, and simulation of an automotive head unit). As input elements can require arbitrary text, a hybrid Automatic Speech Recognition with a local grammar-based speech recognizer and a cloud-based dictation is used. Two smartphone apps demonstrate the technical feasibility and application-independence of our method (the video[2] shows a sample dialog with the calendar app). Natural dialogs and usability was neglected and is a matter of ongoing research.

5. CONCLUSIONS AND FUTURE WORK

This work shows the technical feasibility of a semi-automatic translation method from a GUI to a voice UI based on the CRF. All functions of the GUI are accessible by speech and are adapted to the characteristics of the speech modality. The abstraction of a GUI to UIML guarantees platform-independence for our translation method. However, for each platform the widget set needs to be transformed into abstract GUI elements. Furthermore, using dynamic data ensures app-independence, but requires a data exchange between GUI and SDS. Due to the meta speech dialogs the voice interaction is consistent for all apps and can be adapted to the interaction paradigm of the automotive HMI. The technical feasibility and simplification of multimodal software development has been proven by the prototypical implementation. The next steps focus on the user, which means task-oriented interaction with natural dialogs and an evaluation with user participation in which the driver distraction, task success, and usability will be tested.

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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 explore the design space of natural multi-modal automotive user interfaces and to continue the fruitful discussions held at the 1st Workshop on Automotive Natural User Interfaces from AutomotiveUI '11 in Salzburg, Austria. We would like to analyze where and how new interaction techniques can be integrated into the car.

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; Natural User Interfaces, Gesture Interaction; Speech Interaction.

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 user— 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 nomadic 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. 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 instant 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 and game consoles has brought with it new ways of interacting with computers and embedded devices. Thus, a growing number of people today are used to interacting with touch-sensitive devices (touchscreens and touchpads) and many have some first-hand experience with speech technologies. Within HCI research, "natural user interfaces" (NUIs) 0 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] and natural speech systems like Apple's Siri[2] 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 UIs. Although some early research has been carried out in the automotive context (e.g., [1], [5], [7], [9]), 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]).

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 computer systems is likely to gain prominence in the car-buying decision.

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.
- 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 (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

3. OUTCOMES

We have identified the potential for a fruitful continuation of our 1st workshop on Automotive Natural User Interfaces [8]. 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.

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Eye-based head gestures for interaction in the car

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ABSTRACT
In this paper we suggest using a new method for head gesture recognition in the automotive context. This method involves using only the eye tracker for measuring the head movements through the eye movements when the gaze point is fixed. It allows for identifying a wide range of head gestures that can be used as an alternative input in the multimodal interaction context. Two approaches are described for using this method for interaction with objects inside or outside the car. Some application examples are described where the discrete or continuous head movements in combination with the driver's visual attention can be used for controlling the objects inside the car.

Categories
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces – Interaction styles (e.g., commands, menus, forms, direct manipulation).

General Terms
Human Factors; Measurement.

Keywords
Gaze tracking; Head gesture; Interaction; Eye movements

1. INTRODUCTION
In the last decades, automotive user interfaces have become more complex with much new functionality. Besides controlling the vehicle and operating the primary tasks (maneuvering the car e.g. controlling the speed or checking the distance to other cars), drivers need to interact with a variety of digital devices and applications in the car when driving. However, driver's focus on driving, is still the primary task, and should have the highest priority. The other tasks should be as minimally distracting as possible for the safety reasons [11]. New interaction techniques like speech, touch, gesture recognition, and also gaze have found their way to be used for interaction with user interfaces in a multifunctional space like car. This paper proposes using *eye-based head gestures* as a potential technique for interaction with automotive user interfaces. Eye-based head gesture [13] is a technique for recognizing head gestures. It uses the driver's gaze and eye tracking data for a) distinguishing the gestures from the natural head movements, b) for measuring the head gestures, and c) for using the driver's intention in interaction with objects.

Among the new interaction methods that have so far been studied in the automotive context, techniques like speech and head gestures have the advantage of providing a way for hands-free interaction. However, speech, and head gesture recognition often require a short explicit command like pushing a button before they can be used. Therefore, they can be used in multimodal interaction systems combined with the other input modes and help to minimize the amount of time that the driver's hand is off the steering wheel.

Associated level of physical, visual, and mental workload should be considered when designing a user interface and thinking about the interaction with an automotive user interface [3]. There have been some studies that report that certain kinds of voice-activated interfaces impose inappropriately high cognitive loads and can negatively affect driving performance [5, 6]. The main reason is that we are still far from achieving high-performance automatic speech recognition (ASR) systems. There are also some tasks like controlling radio volume, opening the window just slightly, continuously zoom or scrolling the map which are not intuitive operations to perform solely via speech-based interaction. Speech input cannot also be used when the environment is too noisy. In contrast, head gesture recognition is more reliable and can be a good alternative to speech input. Even if the number of different detected gestures is relatively small, they can be used as both continuous and discrete commands. Interaction by head gestures involves less driver's cognitive load as it can use the natural human communication skills. However the head gesture recognition has been mostly concentrated on detecting head shakes and nods to communicate approval or rejection and as an intuitive alternative in any kind of yes/no decision of system-initiated questions or option dialogs.

On the other hand, much work has been done in driver fatigue detection, and a fatigue monitoring device have been studied as a tool that allow for implicit interaction between the car and the driver to improve driving safety [16]. Eye and the visual behaviors measured by a video-based eye tracker provide significant information about driver's attention [14, 15] and the state of drowsiness and vigilance [18]. A video based eye tracker can also be used for recognizing head gestures using the eye and gaze information. It is possible to detect a wide range of head gestures as well as nods and shakes, which can be used for interaction. Head gestures can also be interpreted as different interaction commands by using the other modalities like gaze and intention proving an inferred interaction.

The paper is organized as follows. Some related works are described in the next section. Then, eye-based head gesture and the interaction method are described. Some application scenarios

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of using the method for interaction with objects in the car are described in a subsequent section and finally we conclude in the last section.

2. RELATED WORK

Many methods for gesture recognition have been proposed and some of them are applied to the automotive environment for detecting the head and hand gestures. Among the non video-based methods, an interesting work was done by Geiger [7], in which a field of infrared distance sensors is used to locate the hand and the head of the driver and sensing the movements. Although the sensor array does not achieve the resolution of a video-based methods, but his system is evaluated to be highly robust in measuring the simple directional gestures. Here, our focus is on the video-based methods for head gesture recognition. Many video-based techniques have been proposed for tracking the user's head and mostly are based on head/face detection and tracking. For example, Althoff [1], developed a system for detecting the head nod and shake using a near infrared imaging approach for interaction in the vehicle. In general, video-based techniques use some features of the face for detecting the head position in 2-D image space [12, 19], or some of them work by fitting a 3D model to the face in each image of the video to provide estimates of the 3D pose of the face [2]. However, these methods are not usually robust enough to strong illumination changes, and usually not accurate and fast enough to be useful for interactive environments.

On the other hands, some attempts have been made to use eye image for head gesture recognition. Concentrating on head gesture recognition methods that use the eye features, Davis and Vaks [4] presented a prototype perceptual user interface for a responsive dialog-box agent. They used IBM PupilCam technology for only detecting the eye location in the image and used together with anthropometric head and face measurements to detect the location of the user's face. A Finite State Machine incorporating the natural timings of the computed head motions was employed for recognition of head gestures (nod=yes, shake=no). Kapoor and Picard [10] introduced an infrared camera synchronized with infrared LEDs to detect the position of the pupils. Recognizing the head gestures had been demonstrated by tracking the eye position over time and a HMM based pattern analyzer was used detecting the nod/shake head gesture in real-time. However, their system used complex hardware and software and had problems with people wearing glasses and with earrings. The most relevant work to this paper is conducted by Ji and Yang [8, 9]. They have proposed a camera-based real-time prototype system for monitoring driver vigilance. An infrared imaging system and the bright/dark pupil effects (similar to PupilCam) is used for detecting the pupil position. They investigated the relationships between face orientation and these pupil features and so that the 3D face (head) pose have been estimated from a set of seven pupil features: inter-pupil distance, sizes of left and right pupils, intensities of left and right pupils, and ellipse ratios of left and right pupils. They have also estimated the driver's gaze and average eye closure speed having the eye images. However, their gaze estimation was limited into nine areas: frontal, left, right, up, down, upper left, upper right, lower left and lower right. Head movements were not measured accurately and what they were interested was to detect if the driver head deviates from its nominal position/orientation for an extended time or too frequently. The same idea for detecting the limited head movement and the rough gaze estimation using the eye images (with different methods) had been also presented before in [17].

3. EYE-BASED HEAD GESTURES

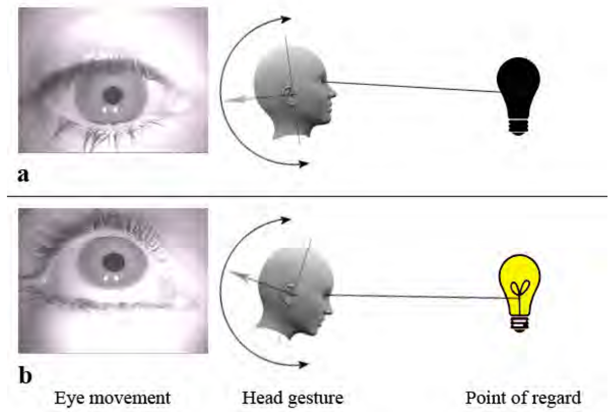

Figure 1: When the gaze point is fixed the head movements can be measured through the eye movements

Eye movements can be caused by the head movements while point of regard (PoR) is fixed or by changing the PoR when the head is fixed. When the point of regard is fixed and the head moves, the eyes move in the opposite direction and with the same speed as the head movement. These eye movements are due to the vestibulo-ocular reflexes (VOR), which are used to stabilize the image on the retina. Figure 1 illustrates a user looking at an object but in two different situations, one when the head is up (Figure 1.a) and the other when the head is down (Figure 1.b). The eye image is different in each posture even though the PoR is fixed. Since the eye trackers measure the eye movements and estimate the point of regard, they are able to measure the head movements when the PoR is fixed. In this paper, the term eye-based head gestures, denotes a predefined pattern of head movements measured through eye movements but where the PoR is fixed on a given object, and the term fixed-gaze target denotes the object that PoR is fixed on it. This method is able to measure a wide range of the head movements (including the head roll) and even though they are very small. The head roll can be detected by measuring the optic flow of the iris pattern and the yaw/pitch movements by tracking the pupil center. Figure 2 shows the basic roll, yaw and pitch movements of the head and the corresponding eye movements in the eye image.

Figure 2: The basic head movements and their corresponding eye movements

This method is independent of the type of the eye tracker and where the data come from and it can be used for head gesture recognition whenever the gaze point and the eye image are available.

Head gestures together with fixed gaze point can be used as a method for gaze based interaction. A combination of fixed gaze and head gestures can be used for interaction with both the objects inside the car and also outside of the car. Two different methods are presented in this section for interaction with objects inside or outside the car. The main reason of separating these two is that fixating the gaze on the objects inside the vehicle during performing the head gesture is not acceptable, and we are interested to minimize the amount of time that the driver's visual attention is away from the forward roadway.

3.1 Interaction with the roadway objects:

For interaction with the objects on the roadway (e.g. getting information about the signs), the driver can simply keep the gaze fixed on the object and then perform a gesture. The eye tracker will recognize the gazed object even though the object and the driver may have a relative movement. When the object has a velocity less than $15°s^{-1}$ in the field of view, the eyes have a slow movement called smooth pursuit. Above this speed the smooth pursuit will be accompanied by saccades. Therefore, these eye movements need to be differentiated from the eye movements caused by the head gestures according to their range of speed. However, in this case, the head rolls can be easily detected by measuring the iris torsion, and can be used as gestures.

3.2 Interaction with the objects inside the car:

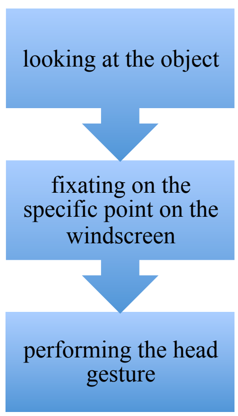

Figure 3: The main 3 steps for interacting with objects inside the vehicle

Interacting with the objects by looking at the object, fixating the gaze on the object, and then performing a head gestures can be useful for some tasks. However, when the task is more complex, this method would not be a safe approach for interaction (e.g. adjusting the side-view mirror in the car). With the method described below, we minimize the time that the gaze is away from the roadway by transferring the fixed-gaze target from a point on the object to a specified point on the windscreen. This point can be indicated by a small dot located on the windscreen in front of the driver. When the target is shown on the windscreen allows the driver to maintain attention to events happening on the road. Therefore, Interaction with the objects inside the car can be done by looking at the object, and then fixating the gaze on a specific point on the windscreen and performing the head gesture. This method uses the driver's visual attention as an implicit interaction modality, so that when the driver looks at an object in the car (e.g. the window) the eye tracker recognize that specific object and then waits for the next step. Once the user fixates on the specific point on the windscreen, the system waits for the user's head gesture for controlling the last intended object.

While performing the gesture, eye tracker measures the eye movements and tracks the gaze point. The distance between the windscreen target and the eye is basically less than 1 meter and therefore the driver's eyes converge during the gesture. The eye tracker can detect this convergence by measuring the distance between the two pupils. Therefore, the convergence of the eyes can be used as an indicator that the driver is performing a gesture.

4. APPLICATION SCENARIOS

Some example applications of using eye-based head gestures in the automotive context are described in this section.

Head gestures have a great potential to be used as an intuitive alternative in any kind of yes/no decision when a system initiated questions or option dialogs. As an example, when the mobile phone is ringing, the incoming calls can be accepted or denied by the head gestures. These simple vertical head gestures can also be used for flipping the rear-view mirror down or up.

The left and right head movements can be used for shortcut functions enabling the user to control the music player and to skip between individual cd-tracks or radio stations.

This method can also be used as a way for interacting between the driver and the head-up display (HUD), enabling the driver to do selecting and for switching between different submenus in a more intuitive way compared to standard button interactions.

Continuous vertical movements of the head can be useful for changing the volume, adjusting the air conditioning temperature, opening and closing the window, and continuously zoom or scrolling the map. In these examples, visual or audio feedback through HUD or speakers can help the driver to perform the task more efficiently. The visual feedback can be a highlight color or even displaying the image of the object. For example, when the driver wants to adjust the side-view mirrors, he/she looks at the mirror and then the eye tracker recognize the mirror as the attended object and then the system shows the real-time image of the mirror in the head-up display. Now, the driver can see the mirror image in front of the windscreen and therefore can easily adjust the mirror by the head movements.

5. Conclusion

In this paper, we suggested to use eye-based head gestures for interaction in the automobile. This method uses only the information extracted from the eye image for measuring the head movements. One of the advantages of this technique is that even very small head movements can be measured through the eye movements. Another advantage is that a video-based eye trackers can potentially be used as one multi-purpose device in the car for head gesture recognition as well as for fatigue detection, monitoring the driver's visual attention, and gaze estimation. Some example applications are described where the gaze and head gestures are used together for controlling some objects in the car. In general, whenever the head gestures are used so far in the automotive context, the new method for head gesture recognition can be applied, too.

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Bullseye: An Automotive Touch Interface that's Always on Target

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ABSTRACT
We present Bullseye, a novel tactile user interface for carrying out entertainment- and information-related tasks in an eyes-busy environment such as a moving vehicle. Bullseye employs standard resistive or capacitive touchscreens or touchpads, but in a radically simplified form. In a traditional touch-based system, inputs must be carried out at particular XY coordinates corresponding to particular on-screen widgets. Bullseye input gestures, by contrast, may be made on the entire surface of the touchscreen or touchpad without regard to widgets' location. It can thereby enable touch applications that require no visual targeting, an approach that may be preferable to traditional visually-intensive touch applications when considering the constraints of the automotive environment. This paper describes the Bullseye approach and a prototype system built with Bullseye.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Input devices and strategies

General Terms
Design, Human Factors.

Keywords
Touchscreens; touchpads; low-attention interfaces; gestural interfaces

1. INTRODUCTION
Touchscreen interfaces have become ubiquitous since the 2007 introduction of the landmark Apple iPhone. Their fundamental advantage is the combination of information presentation (output) and information manipulation (input) into a single unified area, as opposed to requiring two separate areas, with the screen for output and physical widgets for input. A touchscreen's virtual on-screen widgets can be arranged an infinite number of ways to suit any particular application, and new widgets can be invented to meet new needs.

A prerequisite for the direct tactile manipulation of these on-screen widgets, however, is the ability to see these widgets, and furthermore, to keep these widgets in sight for long enough so that the tip of the finger may be brought into contact with a widget's operable area, a process known as targeting.

In certain operating environments such as a moving vehicle, neither of these prerequisites can be taken for granted. The driver's eyes and hands are occupied with her primary task—safely operating the vehicle—and she may only selectively and briefly attend to secondary tasks (operating windshield wipers, turn signals, etc.) and tertiary tasks (operating in-vehicle information systems, or IVIS).[1] This awareness has been established in human factors and HCI circles for many years. In their 2001 report, for example, [4] Burnett et al. noted that "driver-system interactions should make minimal use of the human visual sense," and they call out touchscreen interfaces as particularly problematic because of their need for targeting and their "basic lack of tactile and kinesthetic feedback."

While great strides have been made recently in bringing tactility to touchscreens (e.g., [11][14][15]), this paper focuses on a simpler, cheaper technique that drastically reduces the visual-motor demand of touchscreens by removing the targeting phase from the touch interaction entirely. After a brief look at the related standards and literature, we will describe our "one big target" technique for touchscreens and touchpads, which we call Bullseye, and explain how we integrated it into an interactive prototype.

2. RELATED WORK
2.1 Standards
Industrial and regulatory organizations have created standards that address the potentially distracting effects of manual-visual interaction with IVIS. The Alliance of Automobile Manufacturers (AAM) Driver Focus-Telematics working group states in the 2006 edition of its guidelines [8] that "[s]ystems with visual displays should be designed such that the driver can complete the desired task with sequential glances that are brief enough not to adversely affect driving." The Japan Automobile Manufacturers Association (JAMA) notes that "drivers must be able to shift their visual attention to the forward field whenever necessary" [12]. The U.S. Department of Transportation incorporated aspects of the AAM and JAMA documents into their recently-issued guidelines to manufacturers on driver distraction [7], and the European Commission has in the past issued similar guidelines [5].

2.2 Research
Many researchers have experimented with touch and gestural interfaces to IVIS. Here we will discuss only a handful of these works that strike us as having the most in common with the Bullseye system.

[1] In some formulations, the operation of signals, wipers, etc. is lumped in with steering and acceleration/braking as the driver's primary task, leaving IVIS operation to be labeled as the secondary task. See [13] for more information.

Alpern and Minardo conducted a driving simulation experiment using gestures for map- and entertainment-related IVIS control [1]. Their simplification of the gestural vocabulary into directional gestures (up, down, right, left) and numbers (1 – 5) mirrors Bullseye's use of only the cardinal directions for its swipes.

In their pieTouch prototype, Ecker et al. adapt pie menus to the automotive touchscreen context [9]. One adaptation that they make is that the swipes used to select pie "slices" may terminate anywhere on the screen. The same holds true for Bullseye's navigational swipes.

Bach et al. explore using whole-touchpad gestures similar to ours for the control of music playback [3]. Their subjects found the gestural interface "pleasant and less demanding and distracting" than a conventional target-oriented touchscreen and a tactile (pushbutton) interface, and subjects made the fewest lateral control errors and the fewest medium- and long-duration (>0.5s seconds and >2s, respectively) glances away from the road while using the gestural approach.

2.3 Commercial Deployments

While Audi's MMI Touch [2] features an absolute touchpad in its center console in combination with a multifunction rotary knob, we are not aware of any automobile manufacturers that use a targeting-free touchscreen or a relative touchpad in their human-machine interfaces (HMIs).

The closest analog to Bullseye's "whole screen as target" design comes from the smartphone world, in particular the photo browser and Cover Flow music browser [6] that are found on iPhone and iPod Touch devices (most Android phones have a very similar photo browser). We will explain below what distinguishes Bullseye from these implementations.

3. THE BULLSEYE TOUCH INTERFACE

The central idea behind Bullseye is that the entire surface of the touchscreen or touchpad acts as one large input target rather than a collection of various input targets with various predefined active areas.

Swipes in different directions are mapped to different discrete actions. For example, in our current prototype (which will be described in more detail below), a vertical swipe in the downward direction highlights the previous item in a collection of items, whereas a vertical upwards swipe highlights the next item in a collection of items. Unlike conventional swipe-oriented interfaces, with Bullseye only the direction of the swipe matters, not its point of origin, extent or velocity. Likewise only the number and duration of tap gestures matters, not their XY coordinates (direct coordinates in the case of a touchscreen, mapped coordinates in the case of a touchpad).

A single item from one of the item collections is always in focus, and serves as the implicit target of tap inputs.

4. WHAT MAKES BULLSEYE DIFFERENT

4.1 Touch-Somewhere versus Touch-Anywhere

Conventional direct-touch interfaces require the user to target specific points or enclosed areas on the touchscreen, each of which has a given two-dimensional extent. Typical on-screen elements that must be manipulated include virtual buttons, sliders, knobs, etc. Conventional indirect-touch interfaces (often employing touchpads) afford manipulation of a similar set of widgets, typically via a cursor or pointer that serves as a proxy for the user's finger. Indirect-touch interfaces are also typically positional in nature, in the sense that a finger's position on the touchpad is mapped directly to XY coordinates on the screen ([3] is a notable exception in the automotive realm).

Manipulating widgets using either of these forms of touch interface requires a visually-intensive targeting process; users must continually focus on the screen as they guide their finger or their cursor towards the widget of interest.

Bullseye completely removes this visually intensive targeting process, because the user never needs to activate specific areas or widgets on the screen. All operations can be carried out by swipe gestures and taps anywhere on the entire surface of the screen or touchpad. This means that users can operate the application without looking at the screen itself, or with only the briefest of glances to ascertain the result of a swipe or tap. Spoken or non-speech audio feedback may be used to reduce or obviate the need for even these brief glances.

This makes for a more rough-and-ready flavor of touch interaction. Users can vaguely "paw at" the interaction surface while focusing most of their attention on the primary driving task.

4.2 Continuous versus Discrete Swipes

Smartphones, with their limited screen real estate, have necessitated designs that maximize working area by in some cases eschewing conventional widgets (buttons, lists, etc.) and allowing the user to interact directly with the content itself: for example with album art or with photos. In the iOS version of Cover Flow, one can issue the same rough swipe gestures we make use of in Bullseye. However there are two important differences that we feel make Bullseye more suitable for the automotive context:

Firstly, a slow drag or swipe across a given distance on the Cover Flow screen traverses a different number of items than a fast swipe across the same distance. The exact number of items that have been traversed is not able to be deduced without looking at the screen to observe how many pass through the central focal frame. Similarly, a short-distance swipe traverses fewer items than a swipe over a longer distance. In Bullseye, by contrast, both fast and slow swipes over both short distances and longer distances result in the traversal of exactly one item. In other words, our swipe is a discrete navigation operation, incrementing or decrementing a positional counter by one. A Cover Flow swipe, on the other hand, is a continuous operation, moving the positional counter some number of items forward or backward, where that number depends on the velocity and/or extent of the gesture.

4.3 Single-Target, No Exceptions!

The second difference is that, in addition to the swipe gestures, the Cover Flow and photo browser applications feature dedicated areas on the screen that may be tapped to perform certain special actions, such as the 'i' icon in the lower right hand corner of Cover Flow which changes the focal item's display from album art to a track listing. Tapping the album art in focus does the same thing, and tapping another album outside of the focal frame brings that album into focus. A Bullseye application has no such special on-screen targets for tapping; the entire input surface is one big target. Similarly, there are locations on the Cover Flow screen

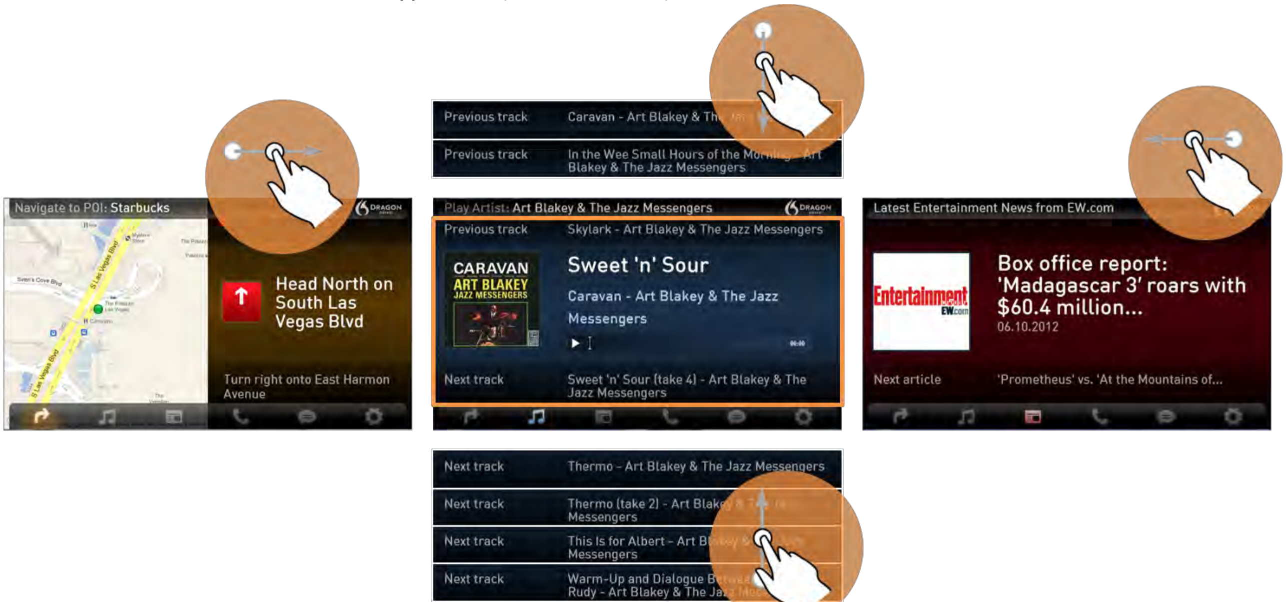

Figure 1. Bullseye swipe interactions in the Dragon Drive! Demonstrator, illustrated from the perspective of a user in the Music screen (swipe icons courtesy of GestureWorks, www.gestureworks.com).

which, if chosen as the origin of the swipe, cause the swipe to have no effect, for example the status bar at the top of the screen. Our system has no such "dead zones;" the entire surface can be employed for any gesture at any time.

5. PROTOTYPE

In recent months we have built an interactive prototype that employs Bullseye as its tactile interface. Dragon Drive! Demonstrator (DDD) is the reference implementation for Nuance's recently-announced Dragon Drive! Platform. It is a multimodal (voice + touch) content search application whose GUI runs on WebKit-enabled mobile browsers and on the Google Chrome browser for Windows PCs.

5.1 Indexed Navigation Interactions

As explained above, swipes in Bullseye are discrete, relative events rather than continuous, absolute inputs. As such, DDD features an index-oriented navigational paradigm. Horizontal swipes cause the various content domains to slide into view, occupying the whole screen. DDD domains include Directions, Music, News, Phone, Messages and Settings, the latter three of which have only sample content in this prototype (although they are supported by the underlying Dragon Drive! Platform). Within each of these domains is a flat (i.e., non-hierarchical) list of items, the content of which depends on the current search term(s)—or lack thereof—in the given domain.

For example, in the screenshot composite shown in Figure 1, at center we see the Music domain after the user has searched by voice for Art Blakey tracks. If the user swiped from left to right, she would activate the Directions domain as depicted at left. If the user instead swiped from right to left while the Music domain was showing, she would be taken to the News domain. In that domain, if no search taken place yet she sees the most recent headlines from her news feed (we have a content licensing agreement with Time Warner's Entertainment Weekly/EW.com).

Within a given domain, the user swipes vertically to move forward and backward within the current search filter's result list, swapping items into and out of the central focal pane, one item per swipe.

Text-to-speech (TTS) based auditory feedback indicates to the user that the system has processed a given navigational swipe input. After horizontal swipes, the name of the newly active domain is played along with any currently active filter. After vertically swiping to activate the next or previous item in a collection, the new item's title is read aloud by the TTS synthesizer. If a user is already at the top or bottom of the list and tries an invalid vertical swipe, the system plays a "bonk" sound effect to indicate that item traversal is not possible. These forms of auditory feedback are essential for eyes-free operation of the system while driving.

5.2 Contextual Actions and Voice Input

The visual prominence and lighter color of the central pane differentiates the selected item. This item serves as the implicit target of a tap (as opposed to swipe) input. A single tap anywhere on the screen or touchpad carries out the default contextual action upon the focal item. If the item is a point of interest (POI), directions to the POI are shown as a swipe-able turn-by-turn list. If the item is a song, the song is played or paused. If the item is a news headline, TTS playback of the corresponding article is started or paused. A double-tap puts DDD into listening mode, where it can accept both contextual voice commands (e.g., "next paragraph" when listening to news article playback) and global commands/searches (e.g., "directions," "music," "latest news on Broadway," "play Aretha Franklin," "navigate to Starbucks"). A long-tap input (tap and hold for more than one second) clears the current search/filter from the currently active domain, re-populating that domain's list with its default content.

6. DISCUSSION AND FUTURE WORK

As the processing power and storage capacity of IVIS continues to improve and their access to Internet-based content becomes faster and more ubiquitous, system designers face a tremendous challenge in creating safe UIs. In order to keep distraction low and user satisfaction high, they must create intuitive techniques for selecting individual items from a vast universe of possibilities (thousands of POI from an onboard DB, millions of songs from a streaming music service, hundreds of news feeds from hundreds of Facebook friends, etc.). Many researchers and practitioners feel that search-oriented HMIs might address this challenge better than hierarchical menus with deeply nested functions and interminably long lists of items (see [10] for more discussion of this point).

Bullseye is well suited for such search-centric system designs. In fact without a suitable alphanumeric input solution such as robust ASR (as in DDD) or handwriting recognition (coming soon to DDD), a Bullseye user would have to swipe once per item in the unfiltered list, a completely impractical prospect once the list gets to be over 10 or 20 items in length.

Whether Bullseye's marriage to alphanumeric input technology is acceptable remains to be seen as we flesh out DDD to incorporate more features and thereby more closely resemble a real production IVIS. Certain domains of functionality, such as climate control, clearly don't lend themselves well to list-based representation, calling instead for physical tactile switches separate from a Bullseye-based touchscreen or touchpad. Are there enough of these non-list-friendly functions to make the car dashboard a sea of buttons and knobs just as intimidating and impenetrable as today's screens bristling with submenus and options? Only further, more functionally complete iterations of our prototype will tell us.

It is also extremely important to conduct formal simulator and vehicle-based usability testing of DDD or other systems built with Bullseye. Can we empirically observe the presumed benefits to eyes-on-road time that come from Bullseye's no-targeting-required eyes-free operability? Is the absolute time required for the swipes and taps in a Bullseye search interaction greater or lesser than for a comparable search interaction with a conventional coordinate-oriented touchscreen? If Bullseye interaction times are indeed longer, might this perceived disadvantage be outweighed by better lateral and/or longitudinal vehicle control in the Bullseye case, or by fewer missed stimuli (say, the brake lights of a lead vehicle in a following task)? These are questions only properly designed experiments can answer.

7. ACKNOWLEDGEMENTS

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Gamification-supported Exploration of Natural User Interfaces

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ABSTRACT
In this paper, we describe a novel concept for motivating users to explore applications using natural user interfaces in the automotive domain. Based on prior findings, it can be very hard for users to detect opportunities of action in such systems. Additionally, traditional "did you know?" hints seem to be ignored by many users today. As a countermeasure, we describe an approach that shall motivate users to explore natural user interfaces by using game elements. By awarding the user with badges and experience level-ups, we hope to create a stronger motivation that is at least maintained until the user is used to the system.

Author Keywords
Gamification; natural user interface exploration; V2X.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

INTRODUCTION AND MOTIVATION
Today's cars have hundreds of features that can be controlled by the driver or other vehicle passengers. Some of the features can easily be accessed via the car's control elements or the in-vehicle infotainment system (IVIS), other features are hidden in deep menus. Car manufacturers try to make access to all functions more intuitive, for example by integrating interactive voice response (IVR) systems into the vehicles. Besides simplifying the access to the functions, natural user interfaces (NUIs) are also introduced for minimizing the driver distraction. However, exploring and remembering artificial gestures and predefined voice commands can be partly also very challenging [6].

In our previous work, we have developed the Android-based driver assistance and awareness system *DriveAssist* [4]. The mobile application runs on the user's personal portable device, such as a smartphone or a tablet PC, which is integrated in the vehicle [3]. The application can derive real time traffic information from vehicle-to-x (V2X) communication services [2] as well as from central traffic services. It could be extended to include other information, both from local sensors as well as nearby vehicles in the future [8]. Since the application is running on modern mobile devices that provide touch input and application programming interfaces to viable speech recognition, a NUI for interacting with the application can be realised without great effort. So far, we are only supporting touch input, but voice recognition is planned in the future as well.

Figure 1. The main screen of *DriveAssist* research prototype. The yellow sticky label-like box in the lower left corner shows random hints for the user. In a first user study, only one out of 12 participants found this way of providing hints useful.

In order to create an intuitively usable software, we have conducted several user studies with *DriveAssist*. Already in one of the first experiments, we noticed that many users were not able to find and use basic functions. Especially subjects that have not been used to modern mobile devices had large difficulties in exploring touch menus, or in performing 'pinch-to-zoom' or rotation gestures. In a second run, we added a yellow randomly chosen "did you know?"-like hint to the main screen (depicted in Fig. 1). However, out of 12 participants working with the application for more than 45 minutes, only 7 did really notice the hint and only one subject stated that s/he found the hint useful.

For that reason, we have created several concepts that could cope with the problem that many functions remain hidden when using natural user interfaces in the automotive domain. In this paper, we want to shortly introduce one concept that uses game elements, such as badges or experience levels, in order to motivate users to explore the application's natural user interface.

RELATED WORK
The use of game design elements in non-gaming context is also known as 'gamification' [1]. Rewarding people with

badges and points for real world behavior can be used to make people try new things or to do things repeatedly. Psychological experiments in the area of educational and professional training have shown that the effect of gamification is triggered by introducing an emotional component [5]. Several examples demonstrate that gamification is working. For example, Foursquare[1] uses the gamification elements 'leaderboards' and 'badges' in order to make people check-in into locations, such as stores, restaurants or outdoor locations.

In addition, people like to share and compare the things they are doing. This is the basis of many social platforms, such as Facebook, Twitter or Google+. An example that combines gamification elements with 'share and compare' is Nike+[2]. On Nike+, users have the ability to track, share and challenge with friends and other runners across the world. Game elements, such as challenges, badges, achievements and rewards create an engaging experience that enriches the real world activity. In the automotive domain, Ford's *MyFord*[3] is a first example of using game elements for deepening the relation to cars through gamification.

Pfleging et al. have also addressed the issue that natural user interfaces can be challenging when they are used isolated in automotive environments [7]. For that reason, they have created the interactive system *SpeeT* that combines touch gestures with speech. Among other things, this system allows making opportunities for action visible to users.

GAMIFICATION FOR NUI EXPLORATION

Since humans like competing, winning, sharing and comparing, we want to bring up the usage of gamification for motivating users to explore functionality of NUIs for discussion. In the following, we have gathered some short thoughts about how such a system could be made up.

The approach could be mainly based on two different types of awards. For more common functions that can be more easily accessed (for example, such that are placed in higher menu levels), a simple one time-awarded badge should be sufficient. This can be used as motivation for exploring little common things. However, the choice of functions for which badges are awarded should not include to many trivial things so that the user has the feeling that s/he is taken seriously. For actions that may be less known to many people, the system could use experience levels that rise with every n-th activation of a function. This would ensures that the users are motivated to use a function for several times. An example could be 'changing the chassis configuration' via the IVR system.

In order to get an overview of what can be explored, the user should have an easy to access list showing all available badges and experience levels. This could, for example, be realized in *DriveAssist* by adding a little cup icon in the main menu. That way, the user can quickly identify what functions are still unexplored or could be explored more. In addition to the awards, a short instruction should be accessible from the overview screen.

An important factor for automotive applications is that the driver is not distracted by any non-driving related action. For that reason, it could be better not to directly award gathered badges or experience level-ups when the car is moving. For example, when the user activated a function while driving, the system could inform her/him about new awards when the car stops for the next time. In cases the car is standing still, the gained badge or experience level should be announced directly. In that way, the user's memory can directly link the performed action with the activated functionality.

In order to make use of the 'share and compare' motivation, the user's social network accounts could be linked to the system. This would allow sharing new badges and experience level-ups directly with the user's friends in real time.

CONCLUSION

Natural user interfaces are a great interaction approach. But in many cases, users do not see the opportunities for action. With our gamification-supported approach, we hope to provide enough motivation for the users to explore NUIs in the automotive domain.

We are currently working on a preliminary concept of this feature and are planning to integrate it into *DriveAssist* in the near future. Afterwards, we plan to conduct a user study in order to analyse the effect of the gamification elements on the users' behavior.

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Experimenting Kinect interactions in the car

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ABSTRACT
As an input device for pervasive computing, the Kinect perfectly fits into several scenarios and use cases. However, pervasive computing typically crafts services and experiences in a new fashion, splitting them into micro-interactions, that needs special attention for designing the best Kinect's usability. We are exploring these new requirements into the car environment, with some insights that can be extended to other scenarios. Our experiments, after initial in-lab tests, are conceived within a new concept for a user interface and visualization for assistive driving.

Categories and Subject Descriptors
H.5.2 User Interfaces – Input devices and strategies

Keywords
Interaction design; Kinect; Natural user interfaces

1. INTRODUCTION
Kinect was born originally as a motion sensing device for video games. Recently, Microsoft released a PC-version of the device, aiming to open the implementation of the interface into several other domains, potentially everywhere, and hopefully generating what Microsoft calls "The Kinect Effect" [1]. Kinect in games and in many other scenarios can be used in different ways. Typically the use cases and the context of interactions require users to interact with the system for a time that can last from few minutes to hours. The concepts of pervasive computing and pervasive interactions open up new scenarios where each interaction with the system, and therefore with the Kinect sensor, can last only few seconds. This rises up new requirements and needs, which we have tried to explore in a specific setting.

1.1 The pervasiveness of touchpoints
In fact, pervasive scenarios redefine the human-computer interaction model and distribute services' touchpoints throughout the whole people everyday experience: through spaces, along time and mindsets.

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Adjunct Proceedings

For this reason, instead of having 'sessions' where users interact for an amount of time with a service, people have and will have more and more a series of single interactions with multiple services. It could be a simple status update about the tracking of an order, the selection of an option from a short list of alternatives, the request for a stock exchange index, the confirmation for a specific action (to sell stocks, buy a ticket, book a flight), etc.

1.2 Touchpoints for micro-interactions
In other terms, people's life will be more and more interrupted with and disseminated of several micro-interactions or micro-transactions. These micro-transactions define all together the lifecycle of the service, which has to be designed and implemented for being 'used' and interacted through several platforms, in different contexts and mindsets. This has an immediate effect on the dynamics of each single interaction. They have to be fast, reliable, and simple. In one word: natural. So from this point of view, user interfaces like the Kinect fit well into these scenarios; however, having to be fast, reliable and simple, they introduce also some additional requirements, that have to be fulfilled.

2. PERVASIVE INTERACTIONS
2.1 A three-steps process
To highlight the main focus of our paper, we introduce a simple model to describe the process through which an interaction with a service happens. In brief, every interaction (in a pervasive scenario, but this is true everywhere) can be roughly described as structured into three steps:

- An *initial step*, where the user is recognized by the system: it can be a login page, an identification system, or a sort of 'wake-up' for the touchpoint.
- A *core step*, where the user, once the contact is successfully established, interacts with the system or the service: it can be short and simple, like an on/off switch or the selection from an options' list, or complex and longer like the management of the entire service.
- A *final step*, where the user can logout, or simply moves away from the touchpoint; this step can sometimes be an optional one: the user simply stops to interact with the system, without logging out or going away.

2.2 The three-steps process for Kinect
When a user interacts with the Kinect, this is how typically the three steps are perceived by her/him:

- An *initial step*, where the user lets her/himself to be recognized by the system: 'waving' her/his hand in front of the camera, or 'raising up' a hand for the same reason, or 'standing up' in front of the sensor: this 'wakes up' the Kinect and allows the system to identify her/himself

- A *core step*, where the user moves her/his body or arm or hand in front of the sensor, and performs some activities and tasks within the application
- A *final step*, where the system 'understands' by itself when the interaction has terminated.

2.3 The three-steps in pervasive scenarios

Usually the core step takes much more time than the other two, and for this reason the main focus is on the user interaction during this phase, while the user performs several tasks and actions with the service, as explained before.

In a pervasive scenario the situation is different: the time spent to pass through the *initial step* and the time needed in the *core step* to do a single micro-interaction are similar. For this reason, it changes the way we have to conceive the whole process.

3. KINECT INTERACTIONS IN THE CAR

In our activities, we have focused on automotive scenarios and on the car environment. In the car of the future drivers will be able to interact not only with the car itself, its devices, components, systems and sub-systems, but also with the outside: location-based services, social network-based services and infotainment services.

3.1 Main requirements

Drivers should be able to instantly receive information about traffic updates, weather forecasts, etc. and to ask the car for them very easily, without distractions. For us, each of these tasks is a micro-interaction with the car system, considered as a whole. Think about this example:

1. First, the driver wants to check if the traffic in the downtown city is ok.
2. A minute later, the driver wants to reply to a received message.
3. Later, the driver raises the volume of the car stereo.
4. After another five minutes, the driver tells the car to find the closest parking slot available.

Each micro-interaction will have its *initial*, *core* and *final* step and each shall be **fast**, **natural**, **and reliable**. In this paper we focus our attention on the 'fast' and 'reliable' requirements, as attributes that can affect also the 'natural' aspects of the interaction.

To have fast micro-interaction, one thing we have to reduce is the time needed to complete the initial step, or the step needed by the car to understand that the user wants to interact with it. We do not consider login, or identification processes, but simply the 'wake up' phase for the Kinect. Therefore, in this initial phase of the project, our main focus is how to reduce this 'wake up' time.

In our experimental settings, we consider the whole windscreen as a surface where the system will project its output, visually. The output consists of simple information like the ones described above, that need to be pointed and selected, with ease, and - again fast. Systems already available in the market, as aftermarket products or shipped from the factories, typically project the information on smaller head-up displays (HUDs).

3.2 Experimenting with the code

Starting from the examples available in the open source literature, we have explored how to tweak and refine timing, algorithms and strategies to reduce the time needed for the initial step.

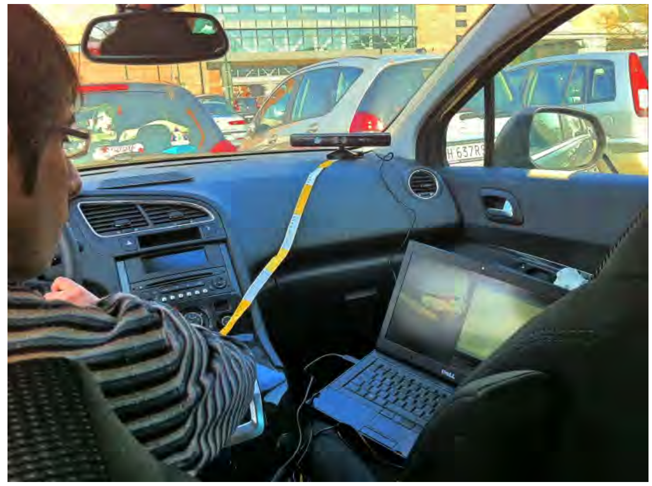

Figure 1 - Reference configuration for a Kinect in a car

Our approach is, after an initial "wave" gesture, to always track the movements; this task was quite obvious and simple to do as the hand of the driver is, at least, close to the steering wheel for the whole duration of the journey. If the passenger next to the driver cause some interference by obscuring the camera or the IR sensor for a while, normally the Kinect sensor is still able to maintain the identification of the driver's hand and therefore to visualize the hand marker. To tweak core interactions to be reliable and fast, we tried several methods. We present here three of them.

3.2.1 The "Wait over marker" method

Our first approach for a system capable of drawing some information on the car's windshield and tracking the user's hand movements over them is a "wait over marker" method.

We draw a single point over the screen every time the position of the tracked hand changes. This will result displaying a "tail" that follows the hand movements. The coordinates for the tail were given by simple indexes capturing the x and y axis values from an available Kinect method. A second circle is draw with a fixed delay time (this can be a user's choice). When the hand stops for a short period in a specific activation area, it triggers the associated action. This method is easy to understand and master, due to its affinity to the 'classic' point-and-click systems. On the other hand, the user/driver has to share her/his attention while driving the vehicle to follow the cursor on the windshield.

3.2.2 The "Push to Activate" method

Three activation areas are displayed on the screen (in green in Figure 2). The Kinect sensor reads the relative position of the x axis with a triggering sequence of the three different activation areas, just moving the tracked hand left or right. This method doesn't require any cursor and at least one of the activation areas is always targeted. It just mimics the "push" gesture (thus changing the z axis) and the target will fire / end the event. This method, however, shorten the distance between the sensor and the tracked hand while the driver is 'pushing': due to the car environment, with an already limited distance, this can decrease the precision of the tracking.

Figure 2 – Activation areas for the "Push to activate" method

3.2.3 The "Circle to Activate" method

Another interesting way to introduce Kinect interactions in automotive environment is to detect circular movements using available methods. We have introduced some changes: we shaped three different activator rings. Rather than change the radius, as in the open source code, activating one ring equals to fire an event. The program checks if the position of the hand marker is placed within an activator ring (in blue in Figure 3); then, if a circular gesture is captured, the system draws a second ring (in yellow, in Figure 3); this ring changes its radius until it matches the activator ring. When the two circles collide, the event is fired.

Figure 3 – Detection of a circular movement

Another thing to note is that the gesture (a circle drawn in the air) recognition can be associated to the radius of the activation's circles; bigger rings equal to wide circular hand movements, while small rings equal to narrow hand movements, until to track just the wrist rotation.

4. THE PILOT STUDY

Our project is aimed at the creation of a prototype able to use new interface paradigms for the human-machine interaction in the automotive sector. One of the purposes of this project is the creation of a configurable prototype to act as a demonstrator able to use new interface paradigms.

4.1 The setup

In order to explore the possibility of an in-car gesture detection system, based on Kinect interactions, we have designed and prototyped a system with two distinct applications, both written in Processing. One application generates data such as speed, acceleration and steering angle, reading and elaborating data from a Logitech G27 steering wheel paired with its pedals and clutch, and writes them to another application that generates the visual output for the windshield. Another application receives data generated by the first one, reads data from other user interface components, together with the Kinect sensor, and creates the visualization for the windshield display.

4.2 The concept for the user interface

The interaction with the system can happen using the Kinect or using more 'traditional' in-car device elements. For the purpose and the scope of this paper we focus our attention only on the interaction with the Kinect. The system can provide two kinds of visualization, projected directly on the inner surface of the whole windshield (at least in the concept, while in the initial proof-of-concepts we projected the images on a smaller surface, similar to a HUD). This type of visualization is somehow close to the Pioneer/Microvision product concept [2]. The first visualization is related with the current speed of the car and the corresponding stopping distance. This information is visualized as a sort of 'shadow', as it was projected by the car in front of itself, with the apparent length equal to the stopping distance.

The second type of information is a set of widgets available to the drivers, to choose and allow to be displayed aside to the 'shadow' (visible in green in Figure 4). These widgets can show data or visualizations about speed, gas mileage, driving info, etc. Widgets can be selected while the car is not moving. During driving, the driver can only choose between selected widgets as in a carousel: only simple interactions are performed during driving, while more complex settings require full attention from the driver, so they are available during stops. The only widget that can't be moved is the "safe brake distance slider"(visible in green in Figure 5).

When the car moves, the system removes the circular control and the driver can see the activated widgets such as the "safe brake distance slider"; this takes place in the lower center area of the driver's point of view and highlights the safe brake distance according to the current speed of the car. In this case the driver can actually see how far (close) the car ahead is from his distance slider in order to adjust (reduce) his speed; the peculiar function of this widget makes its position fixed in front of the driver point of view.

4.3 The preliminary results

We have tested the different interaction techniques described above within our test environment. As preliminary results of the test pilot, one of the suitable solutions involving Kinect sensors is to display only three widgets areas at a time to maintain the cognitive load at an adequate level during driving.

Figure 4 - Selection between widgets

Figure 5 - The interface during the tests

The corresponding activation areas are located at the top of the sensor's action range; those locations avoid the risk to activate something while maneuvering the steering wheel.

The method chosen to deal with the activation zones is a mix between the "wait over marker" and the "push to activate" mentioned above. The latter is used without the "push" gesture: after one second waiting over the marker, the widget is activated.

5. CONCLUSION

The concept of overlaying visual feedbacks on the windshield, with proper luminosity and position, allows a better usage of important information without distracting the driver's eyes out from the line of sight with other visualization devices such as smartphone or on-board monitor, so the user can remain focused on the road. On the other hand, sharing space on the windshield means we have to apply some limitations in terms of quantity (max 3 widgets at once) and design; the widgets, intended to add information and not to hide part of the road, are made as simple as possible with light color and with a transparency degrees chosen by the user in the setup menu.

The usage of a Kinect in an automotive setting seemed to be a very promising novel approach to reduce driver distraction while interacting with the automotive UI, but sometimes we found that drivers need to look at visual feedbacks for a longer time, to search for the cursor, or other feedback, on the windshield.

This can be dangerous in a driving scenario and this leads us to choose the "activation zone" as described before, somehow limiting the usage of Kinect. Our aim is to go deeper into this investigation and move from current results and methods to new and original ones.

6. ACKNOWLEDGMENTS

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Designing & Rapid Prototyping a Gesture-Enabled Steering Wheel

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ABSTRACT
As natural user interfaces become increasingly prevalent in everyday interactions, the Automotive Research team at Intel's Interaction and Experience Research Lab (IXR) sought to explore the potential of touch gestures in the in-car experience. Leveraging common gestures now standard with touch interfaces, we looked at how these standards might extend and adapt to provide a simpler in-car control interface. Through an iterative design process, we conceived, designed, developed, and prototyped an interactive driving demo controlled by a gesture-enabled steering wheel in 8 weeks.

Author Keywords
Natural User Interfaces; Gesture; HUD; Touch; Interaction; Design; Prototyping.

ACM Classification Keywords
H.5.2. [Information interfaces and presentation (e.g. HCI)]: User Interfaces – Interaction styles.

General Terms
Human Factors; Design.

INTRODUCTION
This paper describes the process of designing and prototyping a gesture-enabled steering wheel within the context of an intelligent, connected, HUD-enabled vehicle. Looking at familiar gestures from touch devices, we considered how we might leverage rough swipes and taps to provide a more accessible interface for drivers, with minimal cognitive burden. To support our conceptual vision, we pulled on a number of different skills, prototyping techniques, and off-the-shelf hardware pieces to develop a hi-fidelity proof of concept gesture-enabled steering wheel.

CONCEPT DEVELOPMENT
The initial concept for a gesture-enabled steering wheel arose from several starting points.

1) With Heads Up Displays (HUD) becoming increasingly prevalent, the idea of direct manipulation within the natural touch and visual range of the driver was an interaction model that was identified for exploration, leading to the question of an appropriate input mechanism.

2) Placing controls directly on the steering wheel has become established practice to enable access to functionality without requiring the driver to take their hands away from the steering activity. However, the increasing number of buttons and the need to find and manipulate these directly drove us to consider the opportunity provided by an interface enabled by grosser touch gestures.

3) The prevalence of touchscreen devices has established a common lexicon of swipes and taps that are widely accepted and understood by users, making it a more viable interaction model for the cognitively demanding environment of the driver seat.

The following will describe the process we undertook in order to design, develop, and prototype the gesture wheel which was showcased in live demonstration for the first time at the Intel Developers Forum in Sao Paulo, Brazil in May, 2012 followed by presentation in San Francisco at Research @ Intel Days in June, 2012. The complete cycle from steering wheel concept to first live presentation was completed in 8 weeks.

Figure 1. Interactive Demo Presentation at Research @ Intel Days. LCD TV simulates HUD notifications, while gesture pad embedded in upper right steering wheel spoke enables gesture interaction with the HUD.

RELATED WORK

The allure of touch gesture interfaces in the car is evident in the evolution of in-vehicle interfaces, ranging from research-based to commercial to user-modified. Earlier work in 2007 by Gonzelez et al. [4] looked at thumb-based steering wheel interactions, but focused on a cursor selection model for a long list in the center display. Given the explosion since then of simplified natural interfaces on our mobile devices and technological advances, the paradigm for these touch interactions has shifted and opened up new potential. Beyond providing a fluid and responsive experience, gesture integration can offer the possibility of greater functionality and lower driver distraction, and these benefits are being noted. Döring et al. [2,3] illustrated that gestural input on a touch screen steering wheel can reduce visual demand. Audi has already incorporated character recognition via a touch pad on the surface of the control dial in the center console [1]. Consumers themselves have taken to DIY modifications to incorporate their personal touch devices into their car to support gesture-based interactions while driving [5].

Our design and rapid prototyping efforts align with this landscape as we leverage available tools and technology to explore a high-fidelity gesture-enabled steering wheel experience in a short amount of time.

USER EXPERIENCE DESIGN

The design process was a collaborative effort between several team members, with skill sets including interaction design, industrial design, technology development, ethnography, landscape analysis, and user experience assessment.

Gesture Interaction

When exploring the idea of integrating gestures, we considered the challenging lack of ubiquitous vocabulary around interpretive gestures (meaning gestures that meaningfully translate into specific commands). For this reason, we focused on taps and swipes for easy comprehension, translating these basic, accepted interactions to an appropriate interaction within the context of the vehicle. For the first iteration of the gesture-enabled wheel, we surfaced visual and audio prompts in the HUD simulation that could be handled with the following gestures:

- *Tap* to accept the recommended action
- *Swipe Left* to dismiss
- *Swipe Up/Down* to select different available actions

Visual Interface Design

For visual design, focus was on ease of interaction and communication of concept. Intended for demo rather than long term use, language tended to be more detailed than might actually be implemented in a vehicle.

There were three types of notifications, which dictated the visual language that was settled upon.

Figure 2. Informational Notification with no action.

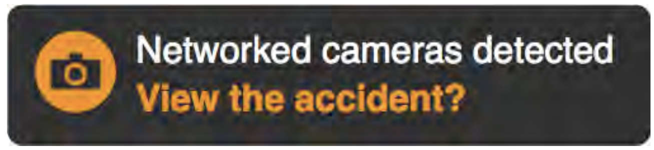

Figure 3. Notification with one available action.

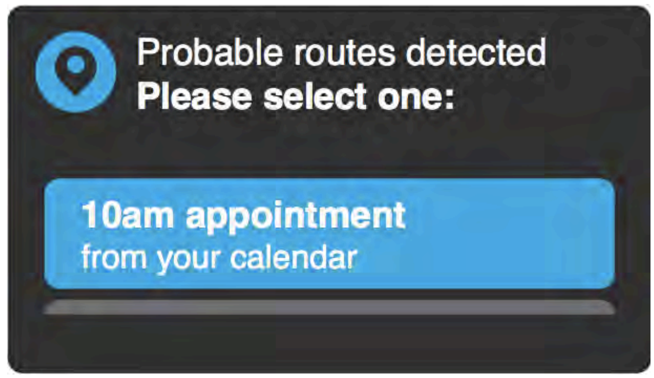

Figure 4. Notification with multiple available actions.

As can be seen from the visuals, color played a strong role in indicating interactivity and type of notification. Because the demo was simulated on an LCD television screen, the colors selected were for clarity of interaction and not for use in an actual in-car HUD.

Input Technology Exploration

Looking into gestures inputs, several off-the-shelf touchpad solutions were considered. However, for greatest control over the form factor of the wheel and responsiveness, we ultimately opted to use the internal capacitive film from a touch sensitive mouse as a flexible input beneath the plastics of our choice.

Figure 5. Capacitive film from off-the-shelf mouse

Industrial Design

Early explorations into the industrial design began with foam core to approximate shape and position on an off-the-shelf steering wheel.

Figure 6. Early foam core prototype of steering wheel gesture pad.

A slight angle felt most natural to us based on the position of the hand on the wheel with the swoop of the thumb. With this in mind, design of the plastics began.

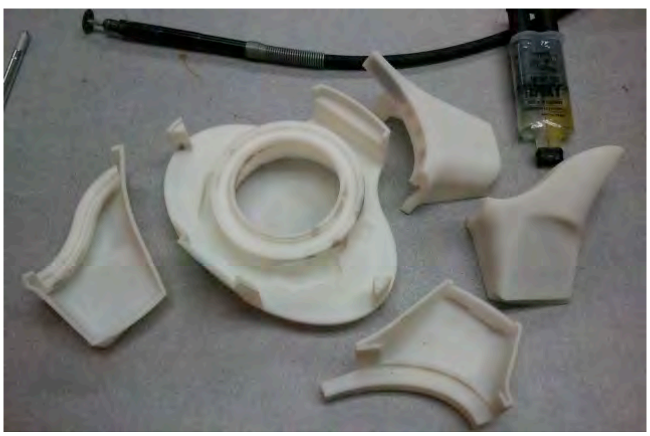

Figure 7. 3D printed plastics to house electronic components and provide gesture pad surface.

The design of the plastics were done in a CAD software program, and were designed with the limitations and of 3d printing in mind, keeping components modular and solid.

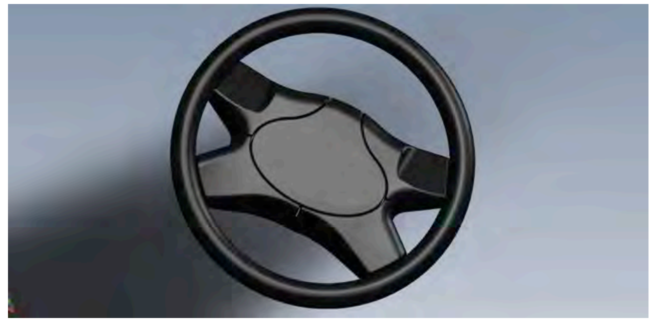

Figure 8. CAD rendering of the first version of plastics.

Plastics were printed in house, allowing for iterative revisions. Although symmetry was alluring both visually and conceptually (as can be seen from the CAD rendering in Figure 8), the interaction model was deemed more confusing (which hand should react when?) and difficult to control (how can I maintain my grip on the wheel and use both thumbs?) based on some quick experiments by team members. We ultimately settled on a division of labor model, where the left hand is the dominant steering hand and the right hand is the control adjustment hand. The final iteration of the wheel had one gesture pad, in the upper right corner of the wheel. Once complete, the electronic components were assembled inside the plastics and the entire construction was mounted on the steering wheel.

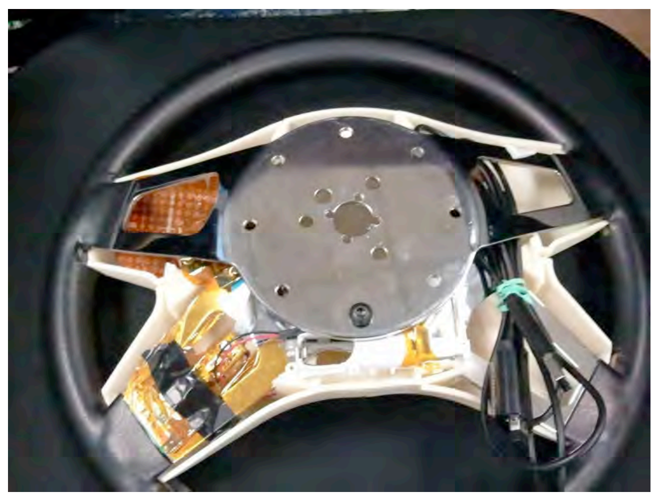

Figure 9. Assembled electronics and plastics on the steering wheel (rear view).

The final wheel was printed in black plastics, and was used to control a demo running on a 46” TV.

Figure 10. Final wheel, mounted in demo simulator.

Software Development

Algorithms were developed to identify swipes and taps, accommodating for arcs or diagonals naturally incurred by users given the positioning of the gesture pad. Given the quick nature of the project, calibration was done based on feedback from various members of the team and other members of the lab.

CHALLENGES & LESSONS LEARNED

The seamless integration of the gesture pad into the plastics actually created some challenges for new users who were not clear where the input was or how it worked. In future iterations, we will be looking at different textures, colors, or other solutions to provide intuitive affordances.

Communication and flexible iteration were key factors in achieving the final output. Being able to quickly gather insights and feedback from different team members and unrelated lab members meant that we were able to at least get some early feedback to support the design process in the absence of proper user testing.

Relying on internal resources and bootstrapped methods meant that we could iterate more quickly without waiting on vendors and services or feeling locked to fabrication methods. However, this did consume time to ramp up with unfamiliar techniques and processes.

NEXT STEPS

Currently, the gesture-enabled steering wheel is undergoing design iterations and qualitative assessment in user interviews. Through these iterations, we are looking into some of the following questions:

- How can we more strongly suggest interactive actions vs. informational notifications?
- How might we strengthen the relationship between the gesture pad and the HUD?
- How can we better assess the viability of this system in a real-life driving situation and over a long term?
- How might we expand the functionality available through the gesture pad?
- How might we explore more complex gestures and do these provide value in this system?

CONCLUSION

The design, development and prototyping of a gesture-enabled steering wheel provide a good case study for the application of available technologies to execute rapid experiential prototyping. With an iterative and collaborate process, the team was able to quickly implement a working prototype that allowed us to experience and observe others experiencing the desired interactions. The process also enabled us to quickly discover pitfalls in the interaction model and to demonstrate our concept in a tangible way. This paper presents an initial prototype created with a multi-disciplinary team in a short time frame. This prototype will lead to further design exploration, user assessment, and concept integration, leveraging the process and learning discovered in this first iteration.

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Emotional Adaptive Vehicle User Interfaces: moderating negative effects of failed technology interactions while driving

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ABSTRACT
Automotive Natural User Interfaces have the potential to increase user experience providing intuitive interactions for drivers. However, in the complex setting of a driving vehicle, failed interactions with in-vehicle technology can lead to frustration and put drivers in a dangerous situation. This paper evaluates the possibility of applying emotion recognition to vehicular spoken dialogue systems in order to adapt the dialog strategies, in error recovery scenarios. An emotional taxonomy is developed for the interactions with a conversational vehicular application, the Voice User Help. The positive results of the performance of VUH emotion recognizer support the creation of real-time classification of the user emotional state, which serves as basis to emotional reappraisal dialog strategies that mitigate negative effects on the driver's cognitive load and driver performance.

Categories and Subject Descriptors
H.5.2 [User Interfaces]: Input devices and strategies, Interaction styles, Natural language, Voice I/O.

General Terms
Measurement, Performance, Design, Experimentation, Human Factors.

Keywords
Voice User Help, Natural User Interfaces, Voice User Interfaces, Affective Computing, Adaptive Interfaces

1. INTRODUCTION
Research in the automotive field has demonstrated that drivers are increasing technology interactions while driving. The use of In-vehicle Infotainment Systems (IVIS), as well as plug-in consumer electronics like smartphones has peaked considerably in recent years [1]. The negative effects of these interactions have raised safety concerns since research has demonstrated that the use of IVIS's increases 25-30% the crash risk [2].

In order to improve driver performance while interacting with in-vehicle technologies, some researchers have looked at Natural User Interfaces (NUI). NUIs have the potential to increase user experience by looking at interaction techniques such as touch, gestures, speech, or full body movements that feel like an extension of a everyday practices [3].

But even when in-vehicle technologies apply natural user interfaces, interactions are not flawless, especially in the complex settings of the moving vehicle. If the output of the interaction is not the expected, users might become irritated or enraged. On the other hand, they might be delighted if the system helps them complete a difficult task successfully. Rosalind Picard introduced these considerations for intelligent computer systems in the nineties by creating the field of *Affective Computing* [4]. Since then, a number of approaches have been developed to create computer programs that are able to recognize and react to emotional states.

This paper evaluates the possibility of applying emotion recognition to vehicular spoken dialogue systems. It is believed that the emotional state of the driver is related to her/his cognitive load and the resources allocated to context awareness. Therefore, the emotional state of the driver can provide useful information to adapt the dialog strategies, especially in the case of unfruitful interactions.

The rest of the paper briefly reviews emotion related automotive research, presents the Voice User Help (VUH), a conversational in-vehicle application, explains an emotional taxonomy developed for the VUH, presents results on emotion recognitions and introduces indications toward using emotional adaptive user interfaces to palliate negative effects during error recovery.

2. AFFECTIVE COMPUTING IN AUTOMOTIVE RESEARCH
Traditionally, emotional taxonomies developed for automotive environments have paid attention to negative emotions that may arise during the driving experience, such as anger that results in road rage behaviors, fatigue and boredom. All these emotions are probable outcomes after long periods of driving or can be consequence of the stress generated during dense traffic situations. Jones and Jonsson studied the affective cues of drivers from spoken interactions with in-car dialog systems. The recorded driver utterances were analyzed by a group of experts and classified into the following taxonomy: boredom, sadness, anger, happiness and surprise [5]. Boril studied the speech production variation during driver interaction with in-vehicle commercial dialog systems. However, his work only considered a neutral and negative emotion classification [6]. Similarly, Wood studied conversations in a driver simulator where participants were asked to give their opinions on topics believed to produce neutral

emotions and topics that conveyed intense (negative) emotions such as death penalty or terrorism [7]. Eyben's general review of affective computing applied to automotive environments discusses the influence of affective states in driving performance with the purpose of identifying main factors for developing counter-steering strategies aiming to position the emotional state of the driver in a neutral / happy state [8]. Eyben proposes an emotional taxonomy for automotive environments where basic emotional states are mixed with other affective states such as moods identifying psychological states that might lead to driver distraction. Therefore, he includes in his taxonomy anger, aggressiveness, fatigue, stress, confusion, nervousness, sadness, boredom and happiness. Grimm studied the effects of positive and negative emotional feedback from the application on driver performance [9].

Other emotional taxonomies for automotive environments have been included in the design of vehicular ontologies in which user modeling is an important part. Feld and Müller introduce in their Automotive Ontology an "emotional state class" with the following possible values: happiness, anxiety, anger, disgust and sadness. Besides the Emotional State they include a mental state characterized by time pressure, level of cognitive load, nervousness and irritation [10]. Islinger identifies in his modeling of the driver's different states based on the recognition of facial expressions. He distinguishes physiological states such as hunger and thirst versus psychological states such as happiness, sadness, anger, anxiety, nervousness, relaxed, bored, stress, attentiveness and drowsiness [11]. These psychological states, originally based on Ekman's [12] and Plutchick's [13] basic emotion taxonomies are adapted to the automotive environment but turn out to be more a collection of emotional and mental states under which someone would need special treatment from an assistive vehicle system, rather than purely emotional states produced as a result of interaction with such a system.

The previously mentioned research has focused on evaluating the effects of emotions in driver performance, rather than reacting to emotional states. Emotions as input parameters for adaptive interfaces in driving environments have not been thoroughly studied since the use of NUIs is a newer field of study. Emotion-related research in the automotive field has, however, supported the notion that "happy drivers are better drivers" [14]. Jeon suggested some emotion adaptation strategies in automotive environments designed to help drivers with Traumatic Brain Injury. He proposes to either modify the emotional state into a desirable emotional state (neutral), using an emotion regulation technique; or attract the complete attention of the driver onto the driving task itself, thus helping the driver to escape from the adverse emotional state [15]. Harris and Nass indicated that positive reappraisal during negative events in the road helped reduce driver frustration and improving driver performance [16]. Other researchers suggest that adapting the system to the same affective state of the user reduces driver distraction [17].

Given the disparity of emotional taxonomies and emotion regulation strategies, an automotive application was created to investigate emotional adaptive natural interfaces.

3. VOICE USER HELP

The Voice User Help (VUH) is a voice-interfaced in-vehicle application that provides vehicle documentation, in the form of informational instructions, using a conversational question-answer interface. The purpose of the application is to overcome the current limitations of in-vehicle manuals and provide user-friendly access to information while driving by means of a user-centered design.

Being a driver assistance system VUH needs to provide intuitive access to information under potentially stressful traffic conditions in which the user can only produce voice inputs and understand simple auditory information. In order to reduce the processing time and effort on the user side the conversational VUH allows natural language input when stating the problems. These inputs typically take the form of questions that the Voice User Help needs to decode, identify and answer. After performing the information search, based on the parameters extracted from the user query, the most optimal answer is presented to the driver. In the case of retrieving the wrong information, an error recovery process analyzes the most plausible cause of the error based on confidence levels of the speech recognizer, the emotional state of the user and the interaction history. Using these parameters the Voice User Help chooses an adapted recovery approach and provides a recommendation on how to reformulate the question for best performance.

4. EMOTIONAL TAXONOMY FOR THE VOICE USER HELP

Given the variety and discordance of emotional taxonomies in the literature, the need to define an emotion classification adapted to a driving environment and the interactions with the Voice User Help was clear. Since VUH can only receive audio input, a group of primary emotions whose attributes were clearly distinguishable from audio data was developed.

Pitterman's taxonomy introduced an adaptive conversational travel agency system [18] that used an adapted emotional taxonomy composed of 7 distinct emotions ranging from negative (anger) to positive (joy). This taxonomy was proposed with the purpose of identifying the user's mental state while interacting with the application. The emotions are ordered in a valence/arousal scale in figure 1. Due to the subjectivity of different emotion theories and the uncertainty of the emotion recognizer the crosses indicate regions where the emotions are located, rather than exact positions.

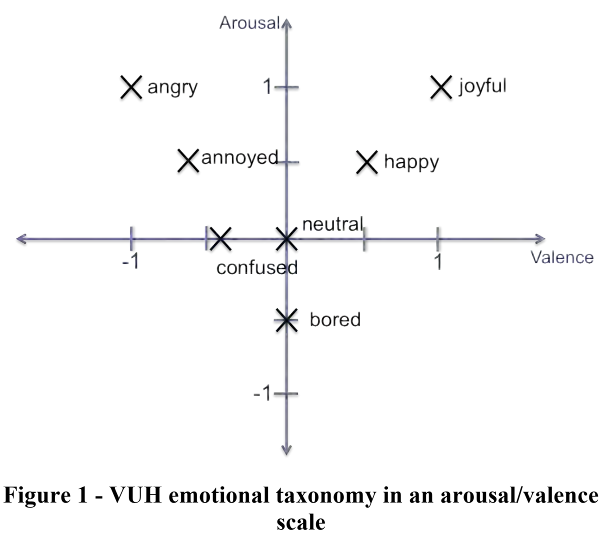

Figure 1 - VUH emotional taxonomy in an arousal/valence scale

Emotions like fear or sadness were ruled out of the taxonomy because they would most likely not be a consequence of the interaction with the VUH. Furthermore, only emotions that provided information for an adaptive interface to modify the interaction were included in the taxonomy. e.g., if the user was in a sad emotional state, the user interface would do a poor job in trying to comfort her/him.

5. EMOTION RECOGNIZER

The emotion recognizer of the VUH used the software Praat v.5.3.03 [19], to extract the prosodic values that conformed the emotional vector and the Weka data mining tool [20] to train each emotion recognition model and evaluate the classification algorithm that might produce the best results.

The emotion was calculated in real time using a Praat script that extracts, Mel frequency cepstral coefficients as well as values of pitch, intensity and power. Mean values and derivatives of each feature comprised the 21-feature vector. Using this data, a speaker dependent recognizer was developed.

Different sample sizes were analyzed to evaluate the minimum sample size needed for an emotional corpus to provide high performance. The results, presented in Table 1, show that even with small emotional data samples a personalized emotion recognizer performs good using Logistic Model Trees (LMT), Multi-Layer Perceptrons and Simple Logistic regression classifiers, around 70% recognition success.

Table 1 - Performance of Weka algorithms on Emotion classification

Algorithm	Training Cases			
	49	98	245	490
Ibk	57.14	61.22	82.45	85.51
LMT	**71.43**	**78.57**	**83.56**	**90.00**
MultiClass Classifier	55.10	68.37	76.73	87.35
Multi-Layer Perceptron	69.39	76.53	85.71	88.98
NaiveBayes	59.18	67.35	76.33	79.39
SimpleLogistic	71.43	78.57	85.31	88.16

The results showed that with a limited number of iterations (less than 500 utterances) the LMT classifier could perform up to 90% accuracy on the 7-emotion taxonomy.

6. HISTORY DIALOG VARIABLES

Besides the real-time emotion recognition during the interactions with the VUH, other dialog history variables help the dialog manager during error recovery scenarios.

A “Connection Error Count” keeps track of the number of connection errors between the front end and the back-end of the application. Establishing a threshold, the application can suggest that the user to terminate the interaction due to errors in the telematics system, and encourage him/her to try again later. This would potentially prevent high levels of driver distraction due to longer and increasingly frustrating interactions.

Furthermore, a “Negative Turns Count” keeps track of the number of wrong answers presented to the user during the application life cycle. Different dialog strategies might take place depending on the increasing value of this variable to adapt the interaction to a growing negative state resulting of unsuccessful searches.

7. DIALOG ADAPTATION STRATEGIES

Using the above-described emotional states and the dialog history variables as inputs, the Voice User Help is able to recognize dangerous interactions that could potentially put the driver at risk and can take the decision to actively interrupt the interaction for safety purposes, or try to apply some emotional regulation technique.

However, it is not yet clear what would be the best approach to deal with emotions while driving in order to assist driver performance and increase user satisfaction. While some research indicates that adjusting the emotional state of the application to the emotional state displayed by the driver will increase user satisfaction as well as reduce driver distraction, others vote for neutralizing any emotional state to a neutral state or rather drive the driver to a positive emotional state.

On going research is looking at the effects on driver performance and cognitive load of emotion matching and emotion neutralization compared to the use of the Voice User Help with no emotion adaptation. Further research questions investigate if during error recovery scenarios informational feedback is preferred to apologetic feedback.

Preliminary results seem to support that emotion neutralization techniques help users under negative emotional states to reduce the cognitive load and improve driver performance while emotional matching techniques help participants experiencing positive emotional states to keep a positive to neutral state during error recovery scenarios. We will also explore new parameters relatives to emotional level.

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Natural Visual User Interfaces – Beyond Input Modalities

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ABSTRACT

The understanding of Natural User Interfaces (NUIs) commonly refers to user input which is often realized through speech or gesture interaction. However, car manufacturers have not yet extensively integrated natural input into their products. In our opinion, the feedback channel back to the driver as well as natural output modalities have been neglected in the discussions of NUIs. Visual presentations that integrate strategies of human visual perception can possibly serve as an appropriate output channel, enrich speech and gesture interaction with feedback and in turn increase user acceptance. We propose the integration of stereoscopic or large display solutions for the development of NUI concepts. Our approach allows for a seamless integration of displays into the vehicle's environment and interior so that the borders between virtual and physical space become indistinct.

In this paper, we discuss potentials and limitations of Natural Visual User Interfaces (NVUIs) in an automotive context. We provide first steps towards assessing the design space of visual output for NUIs to inspire future research.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User interfaces – *Graphical user interfaces (GUI), Interaction styles (e.g., commands, menus, forms, direct manipulation).*

Keywords

Automotive user interfaces; graphical user interfaces; large display spaces; natural user interfaces; stereoscopic displays.

1. INTRODUCTION

The aim of designing NUIs is to turn the human machine interface (HMI) invisible by providing natural and easy to learn interactions. Recent investigations in NUIs concentrate on input design and more concrete on speech and gestures [8]. In general, UI development affects not only the communication and translation of the user's intended goals to the system but a much richer scope of presenting information [4]. We claim that NUIs need appropriate user feedback and output of the system's current state. In particular, automotive user interfaces have to provide urgent information about the vehicle's state and the driving situation in a comprehensible way. This is the case for visualizing information related to primary (e.g. velocity) and secondary tasks (e.g. indicator). Tertiary tasks (e.g. initiating a phone call, browse music library) offer a design space that allows the application of natural input techniques as gesture and speech. This paper discusses the shortcomings of these input techniques and proposes natural output modalities which might foster a more natural interaction with the car's user interface. We focus on visual output and suggest the integration of modern display technologies as autostereoscopic and large displays. In this context, we elucidate risks and potentials for NUIs inside the car and highlight opportunities for future work.

2. COMMUNICATION CHANNELS

In general, NUIs are understood as synonym for speech and gesture interaction. In the following, we discuss these input channels. Furthermore, we consider different output channels and estimate their contribution to NUIs in the automotive context. Thereby, we highlight the special role of visual feedback.

2.1 Typical Input Modalities for NUIs

Speech is one of the basic communication channels between humans. However, current speech input in cars is less natural since they are command-based. Alvarez et al. [1] tackle this problem by applying natural conversations as input modality and auditory system responses for output. Nevertheless, we think that people have inhibitions to talk to machines [3]. Moreover, users can phrase their goals in various ways which complicates the unambiguous interpretation of speech input even more.

Human communication heavily builds on body language as a modality to transmit information. In human-machine communication, gesture input is commonly applied for touch displays and freehand interaction. Touch gestures are integrated in cars already. However, it is often not clear in which parts of the screen a touch interaction can take place and which parts are inaccessible. Beside touch gestures, there is current research about freehand interaction in the vehicle [5]. Car manufacturers have not yet integrated freehand gestures in their products but are working hard to make it a part of the HMI of future vehicles. One of the problems they face is ambiguity; starting a certain action would require an activation gesture to prevent non-intended input. Moreover, in most use cases gestures induce an abstract function matching so the user needs to learn how to perform a specific action to trigger a function.

2.2 Output Modalities for NUIs

Auditory output in form of speech can transmit rich information. However, processing time causes delays in perception. The temporal dependency on the moment of output limits the driver in focusing on the feedback. This can be useful for urgent information transmission, for example abstract alert sounds. However, those cannot communicate a lot of information. For any kind of auditory output, the driver cannot choose the moment of attention switch. If the driving situation does not allow the perception, the temporal-dependent presentation is missed.

Haptic output can be used as feedback to enhance gestural interaction. For example, touch displays do not provide perceivable shapes of the displayed controls and confirming feedback while manipulation. Tactile feedback in form of vibrations is one way to compensate the lack of haptic feedback. With freehand gestures, the driver does not have a physical connection to the controls, suggesting the application of remote tactile feedback [6]. However, tactile output can interfere with car vibrations, making it unperceivable. Furthermore, haptic output is used to encode spatially related information like indicating an unintended lane change to the left or right. Similar to auditory alerts, the information density is limited and not sufficient for presenting complex information.

In contrast to the previously discussed output channels, the visual channel is rich and can present a large amount of information in a short time frame. Since the visual channel provides most important feedback for the primary driving task, it is crucial to design visual output in a reasonable way. The most important issue is to control information overload to inhibit perceptual tunneling and cognitive capture on the driver's side [7]. The reasons for particularly engaging interfaces have to be identified and avoided. Keeping these criteria in mind, the next section discusses the potential of visual output for NUIs.

3. VISUAL OUTPUT FOR NUI

We propose visual output as a new output channel for NUIs. We want to translate existing human visual perception strategies into HMI concepts in an automotive context. We claim that a natural visual presentation requires a seamless integration of displays into their environment. In this case, seamlessness is not restricted to the physical construction into the cockpit's surface but also includes the integration of the displayed content into the real world. We consider that such a visual output can enhance existing natural input, as speech and gesture, by providing a natural visualization of feedback, virtual content, and the vehicle's state. Furthermore, representing the car in a natural way possibly fosters the communication between driver and vehicle.

In the following, we present concrete approaches by discussing stereoscopic and large displays for NUIs in the car. At this point, we do not give a definition of natural visual output. Instead, we aim at motivating starting points for the design of visualization concepts to integrate natural input and output.

3.1 Stereoscopic Displays

Humans have a three-dimensional vision through the perception of horizontally shifted images. The discrepancy between the two projections onto the retinas enables an internal spatial representation of the environment. Stereoscopic displays generate an illusion of depth on a flat surface by presenting two distinct images to the viewer's eyes. Since humans perceive their environment with two eyes, this technology possibly fosters the naturalness of information visualization. Realistic spatial presentations can encourage the user to explore natural input techniques as freehand gestures. Moreover, the use of 3D depth allows structuring the displayed content, for example by putting the interaction focus to the foreground [2] or, for touch interaction, pushing inaccessible objects to the back.

Stereoscopic technologies use several encoding and decoding strategies for a correct projection of the two images into the eyes. Glasses-based technologies are not sufficient for an in-car situation since it is not applicable to force the driver to wear glasses in order to perceive the user interface correctly. Autostereoscopic approaches do not require any headgear to create a spatial impression. However, these technologies are limited to defined spatial areas where the viewer's eyes perceive the respective images. Tracking the position of the user and adjusting the viewing zones in accordance provides wider degrees of freedom for head movements. This technological approach simultaneously offers the integration of motion parallax which makes the spatial impression even more natural. The peril of stereoscopic technologies is that they can cause visual fatigue. We consider that future technological developments, e.g. holographic and volumetric displays, and appropriate content design can compensate this risk.

3.2 Large Display Spaces

Integrating screens that offer a large surface for the presentation of information and that are distributed over the cockpit's area result in what we call large display spaces. Different concept cars have been presented that integrate large display spaces spanning over the whole cockpit, like DICE[1] or Fun Vii[2].

Currently integrated screens do not take advantage of the large human field of view but clutter the huge amount of information on a small spot of the available cockpit area. The size of large display spaces offers the possibility to declutter virtual presentations in the human field of view by logically structuring the information. A spacious presentation of information can support the perception of content by giving room for natural visualizations and by localizing them according to their semantics. For example, rarely used content can be placed further away. Large display spaces present an overview of available information and starting points for enabling different functions concurrently. In combination with freehand gestures and touch functionality distributed over the cockpit's display spaces, various functions can be directly accessed without transitions in the menu hierarchy.

4. CONCLUSION AND FUTURE WORK

This paper aims at integrating visual output to enhance NUIs. We argue that the output channel has been neglected in discussions about NUIs. Information can be presented in a way users know from real life. We proposed stereoscopic and large displays as a natural output channel. Both approaches provide space for structuring information by using 3D depth or large areas. Speech and gesture interaction can benefit though a consistent visual presentation. Visual output has the potential to transmit rich information at one glance. However, the visual channel is the main feedback channel for the driver's primary task driving. Therefore, we structure our research as follows. We will develop interaction concepts integrating stereoscopic and large displays and implement them in prototypical realizations. We evaluate the concepts in driving situations to assess, and iteratively exclude, negative effects on driving performance and workload. Moreover, we believe that the presented output approaches increase joy of use and attractiveness.

In summary, we want to enrich the discussion of NUIs by adding visual output as a further modality to existing input approaches, facilitating future driver-vehicle communication.

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Workshop „CLW 2012: The 2nd Workshop on Cognitive Load and In-Vehicle Human-Machine Interaction“

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CLW 2012: The Second 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 helps 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, and will also endeavor to provide guidance on problems, goals, hypotheses and approaches for future research in this area.

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) requires varying degrees of visual and cognitive resources. Concerns over excessive visual demands in the vehicle have existed for some time. More recently concerns over the impact of HMI on drivers' cognitive resources have gained attention. While multiple definitions of cognitive load (also called cognitive or mental workload) appear in the literature (see [1] 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 [2]. A central question in designing HMI for in-vehicle devices is how the HMI will impact the driver's cognitive load [3]. In-vehicle devices are often operated while the vehicle is moving. While the primary task of the driver is to ensure driving safety, the availability of such devices often lures drivers into getting engaged in peripheral tasks while driving. Poorly designed HMI requires an increased level of cognitive resources, reducing the driver's ability to dedicate sufficient cognitive resources to the driving task, and can lead to possibly disastrous consequences. The Yerkes-Dodson Law provides a theoretical background for modeling the effect of driver cognitive load on driving performance, and can be seen as a pivotal concept in the detection and management of cognitive load [4]. While research results on in-vehicle cognitive load are frequently presented at automotive research conferences and in related journals, CLW 2012, the second in the series [5], 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 sometimes seems illusive. What exactly is cognitive load? The workshop will explore different points of view on this question.
2. **Explore issues in cognitive load estimation:** Estimating cognitive load while driving is a challenging task. Clearly, our understanding of estimation is tightly coupled to our definition of cognitive load. However, whatever the definition we use, estimation (on-road [6][7], and laboratory-based [8][9]), focuses on three types of measures: performance, physiological and subjective. The workshop will explore the practical use of these measures in on-road studies and those performed in a laboratory setting (both using immersive driving simulators and other techniques).
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 [10], 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 [11][12], augmented reality [13][14], mediation [15], tactile interfaces [16], subliminal notifications [17], etc.). Other work [4] suggests that effective implementations of these and

other systems need to adapt to the driver's state. The workshop will explore various aspects of managing the driver's cognitive load.

4. **Explore paths for future research and development:** In light of current approaches to cognitive load estimation and management, what research and development avenues should be explored in the next 2-10 years? Workshop participants will discuss (a subset of) problems to be explored, goals to be set, hypotheses to be tested, and approaches likely to be fruitful in testing these hypotheses.

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 paths for future research and development (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.

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,
- 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 [18]. 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 have three sessions.

Session 1: What is cognitive load? 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.

Session 2: Cognitive load and in-vehicle HMI research. Session 2 will feature poster presentations by workshop participants. These will be preceded by a one-minute-madness session, allowing each presenter to briefly introduce his/her poster. The presentations will focus on cognitive load estimation and management, specifically the topics listed at the end of section 2.

Session 3: What's next? In the final session we will invite participants to discuss the results of the first two sessions in small groups. We will propose three seed questions for discussion:

1) How are the research problems, goals, hypotheses and approaches identified in the first two sessions related to each other?

2) What are the societal forces that are shaping the direction of our research?

3) In light of answers to the first two questions, what are some desirable partnerships and collaborations that would promote progress towards solving the major problems identified in this workshop?

The conclusions from the small-group discussions will be presented in a closing round-table discussion.

3.2.2 Collecting Feedback

As in 2011, 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 prepare and post a separate report about participant evaluations.

3.3.2 White Paper(s) on Future Work

The organizers will initiate an effort to prepare one or more white papers to provide guidance on future work in the field of cognitive load as it relates to in-vehicle HMI. As there are various intended consumers of this guidance, from fellow researchers and developers, to industry, to funding agencies, more than one white paper might be appropriate, each with a different focus and format.

3.3.3 Workshop at AutomotiveUI 2013?

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 2013.

4. ACKNOWLEDGMENTS

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The Impact of Central Executive Function Loadings on Driving-Related Performance

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ABSTRACT

The study reported in this paper investigated the impact of individual ability, with respect to central executive (CE) functions, on performance of two driving-related tasks when distracted by CE loading secondary tasks. The two driving-related tasks used were visual target detection, and a one-dimensional pedal-tracking task designed to be an analogue of a vehicle following task. The three CE tasks were each designed to load mainly on just one of three different CE functions (inhibition, shifting, and updating, respectively) in both audio and visual conditions. An additional single key press secondary task was used to assess the impact of a non-CE loading secondary task. We hypothesized that people with a higher level of ability for a given CE function would do better, relative to those with lower ability, on the driving-related task when it was accompanied by a secondary task that loaded the corresponding CE function. 102 people participated in the screening portion of the study, and 34 of these participants were then selected to participate in the main experiment. We found that the impact of CE abilities on dual task performance is more complex than a simple tradeoff model would predict. Shifting ability generally improved primary task performance in the dual tasks, and inhibition ability tended to improve performance in the target detection task, while updating ability tended to improve performance in the pedal-tracking task.

Keywords

Driver distraction, Mental/cognitive workload, Central Executive, Individual differences, Inhibition, Shifting, Updating, In-Vehicle information device, User interface

1. INTRODUCTION

The long-term goal of this research is to identify interaction design requirements for minimizing the distracting effect of in-vehicle information systems on drivers. We focus in particular on the distraction and workload caused by tasks that place a load on the central executive (CE) functions. CE is one of the main components in the dominant model of working memory (e.g.,[1]). Extensive research has associated CE function activity with the prefrontal cortical region of the brain (e.g.,[16]).

Driver distraction caused by interaction with in-car information systems involves multi-tasking situations that likely comprise several types of workload, including perceptual (visual and audio), manual and cognitive workload involving central executive functions [18]. In the research reported here we focused on cognitive workload and investigated its effects on driving-related performance. We were particularly interested in using individual differences in cognitive ability (CE functions) as a way to identify when higher levels of CE function ability are needed to maintain adequate driving performance in the presence of distracting secondary tasks.

2. RELATED RESEARCH

2.1 Fractionated CE functions and Individual Differences

There has been considerable discussion around the issue of whether CE functioning should be understood as a unified system or as a fractionated system. The fractionated system view has mainly been supported by studies on individual difference in cognitive ability, which have been conducted with a variety of populations, such as normal young adults [17][9], normal elderly adults [13], brain-damaged adults [3], and children with neurocognitive pathologies [11]. These studies typically employed a battery of widely used executive tasks like the Wisconsin card sort test (WCST) and the n-back test, and examined how well these tasks correlated with one another by performing correlation/regression analysis and exploratory factor analysis (EFA). Many of these studies have shown low (not statistically significant) inter-correlations among different executive tasks, consistent with the fractionated system view.

Observations from neuropsychology have also supported the fractionated view of CE functioning. For example, Logie et al. examined the basis for a multiplicity of CE functions, showing that the function for multitasking could be selectively impaired in Alzheimer's disease (AD) patients group [12].

In the fractionated CE view, a variety of ways to classify executive functions have been proposed such as "mental set shifting", "inhibition", "flexibility", "updating", "monitoring", "planning", and "dual-tasking". In this research, we decided to start our exploratory study from the following three functions: "inhibition", "shifting", and "updating" based on Miyake et al's characterization [17], since the three functions, or analogous ones, are often seen in other classification systems (e.g., [19]). In addition, each of these three functions have been associated with tasks that can be used to measure the level of ability that a person has with respect to that function.

Some researchers have argued that these three functions differ in their degree of independence. For instance, Szmalec et al. argued that updating ability as measured by the n-back task includes an aspect of conflict solving that is related to inhibition [25]. While it is probably difficult, if not impossible, to develop "pure" tasks that load on only one CE function (since tasks will generally have shared perceptual, selective attention, and response selection components), it should still be possible to assess the impact of CE functions using "impure" tasks that tend to have high loadings on one CE function relative to the others.

2.2 Multiple resource model and multitasking performance

Wickens proposed a multiple resource model to describe cognitive (mental) workload [27]. In the multiple resource model there separable attentional resources (for example, visual and auditory in modalities, spatial and verbal in codes). In this research, we are interested in whether or not the multiple resource model should be extended to include the impact of different CE functions, and we are also interested in the impact of individual differences on those CE functions.

To measure cognitive workload, a dual-task procedure is often used. In the literature review on the use of secondary tasks in the assessment of workload, Ogden et al. found that there is no single best task or class of tasks for the measurement of workload [20] (also see [6], for a collection of chapters on the different approaches to measuring mental workload). Given the strong evidence for a multiplicity of CE functions, it is natural to ask what role, if any, they should have in models of mental workload and cognitive distraction. This question was the motivation for the research reported below.

2.3 CE functions and driving performance

While many researchers have tried to measure the levels of driver distraction caused by different secondary tasks (eg. [7][15][24]), relatively little research has focused on understanding the types of cognitive workload and their effects.

However, Baumann et al. investigated the effect of CE load on driving performance (as assessed by time to collision and driving speed) [2]. They used simulated driving where participants were required to avoid obstacles while performing either an auditory monitoring task that should not load on the comprehension functions of the CE, or a running memory task that should heavily load on the CE involving comprehension and prediction function of situation awareness. They found that participants received less benefit from being provided with a warning signal when they had to perform the running memory task. The researchers concluded that the CE function is strongly involved in the construction of situation awareness.

Mäntylä et al. also examined the relationship between CE function and driving performance [14]. In their experiment, high school students completed a simulated driving task and six experimental tasks that tapped the three CE functions of inhibition, shifting, and updating. Their results showed that updating ability was a significant predictor of performance on a Lane Change Task (LCT) while doing simulated driving.

3. OUR RESEARCH INTEREST AND HYPOTHESIS

In the present study, we assumed that workload experienced by individuals is defined as the interaction between individual differences and task requirements. Figure 1 represents our approach, where workload is attributable to task loadings on the three CE functions of inhibition, shifting, and updating. The model makes the following three assumptions:

- Individual differences exist in the capacity of each CE function;

- Different tasks load the CE to varying extents as a function of both the nature of the task itself and the unique effect of the task on each individual.

- The cognitive workload that a person experiences while performing a task is determined by the direction and degree of mismatch between the person's abilities and the task requirements with respect to the CE functions.

If validated, this model provides for the profiling of tasks by measuring the CE ability of individuals and the subsequent cognitive workload they experience while performing those tasks. Tasks with unacceptably high loads on particular CE functions could then be identified and redesigned so as to reduce those loads to acceptable levels. Figure 1 summarizes this approach whereby cognitive demands by a task (pick bars on the left) combine with individual cognitive ability (green bars in the middle) and result in workload predictions across each of the three CE functions (blue circles on the right). For instance, participant 1 has low shifting ability and the task requires high shifting ability, meaning Participant 1's shifting workload is high for that task.

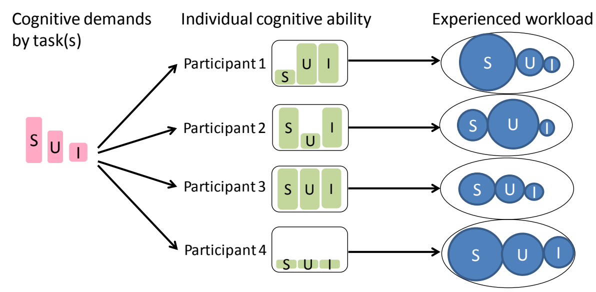

Figure 1. A model of cognitive workload based on the individual differences and different task requirements

In a driving task it seems that all three CE functions (inhibition, shifting, and updating) are required. Updating is likely required for keeping track of the position of one's vehicle relative to other vehicles in the road, and of keeping track of one's current location for navigation purposes. Inhibition would seem to be required to detect and respond to external events such as changing traffic signals or people who move into the path of one's vehicle. Finally, since driving often involves multi-tasking, shifting ability will be involving in managing the process of switching between the main driving task and other tasks. However, people with wide ranging cognitive abilities appear to perform well at driving. Thus it seems that the traditional driving task is not overloading CE function ability for most people.

What happens, though, when novel in-vehicle information technologies create demanding new secondary tasks? Could it be that some CE functions become overloaded with a corresponding decrement in driving performance and a decrease in safety? In order to test whether this is a far-fetched concern or not, we designed the experiment below to examine the impact of CE function ability on driving performance when CE loading tasks are involved. Should concerns about CE loading prove to be justified, the methodology used in this paper (assessing the impact of CE abilities on driving in the context of CE loading secondary tasks) may help to find problems relating to CE function loading in in-vehicle interfaces.

We developed the following hypotheses to test in the experiment:

1. Effect of Cognitive workload

An individual's ability on a particular CE function will be significantly related to primary task (driving-related task) performance when also performing a secondary task loading on that CE function. To test this we used a series of regression analyses with performance on the primary task (either pedal tracking or target detection) as the criterion, and measured levels of individual ability (inhibition, updating, and shifting) as the predictor variables. Forward and backward stepwise analyses were run with one pair of analyses for each combination of primary task complexity (block 1 was lower complexity, block 2 was higher complexity), modality (auditory or visual) and type of loading on the secondary task (inhibition, shifting, or updating).

We expected that the overall pattern of results in the regression analyses would tell us the extent to which CE function ability was driving primary task performance, and in what contexts. If a particular CE function ability was only a significant predictor of primary task performance when the secondary task loaded on that same CE function, then that would show that the secondary task was harming primary task performance because of its loading on that function.

Alternatively, if the presence of the secondary task in itself was making loading on the primary task more critical, then we might expect to see different CE abilities affecting performance on the two primary tasks, regardless of which CE function loaded the secondary task. Specifically, we would predict in this case that performance on the pedal tracking task would be significantly related to updating ability, while performance on the target detection task would be significantly related to inhibition ability. In addition, to the extent that shifting is related to task switching we would expect it to be significantly related to primary task performance in all the dual task conditions.

2. Effect of Perceptual workload

Overall experienced workload is a combination of visual (or perceptual), manual and cognitive workloads. Since both the main and CE tasks involve visual processing, we would expect overall workload to be higher when the information in the secondary task is presented visually due to the resulting high load on visual attentional resources (cf. [27]). However, it could also be hypothesized that mental workload could rise, rather than fall when an audio secondary task was used due to the fact that auditory information tends to require more storage in working memory.

4. SCREENING TEST

Prior to the experiment, we conducted a screening test to select people who cover a range of different cognitive profiles with respect to the three CE functions considered in this research.

4.1 Method

4.1.1 Participants

102 people participated in the screening test. Participants were recruited through recruiting firms, emails to distribution lists and from notices posted on University of Toronto campus bulletin boards. The participants consists of 53 males and 49 females, aged from 16 to 64 years old (M=42.3, SD=13.4). All of the participants were English speakers living in the Toronto area with normal vision and hearing.

4.1.2 Tasks

We selected three cognitive tests to measure each participant's CE ability based on Miyake et al.'s findings concerning the mappings between tasks and CE functions [17].

(1) Stroop test (Inhibition): Six color words ('black', 'white', 'yellow', 'orange', 'purple', and 'green') were presented in one of the six same font colors individually and at random. There were 36 possible word-font color combinations. On each trial, three color names (response alternatives) were presented in black at the bottom of the display. The participant's task was to respond with the color in which the stimulus word was written, by pressing a corresponding key. The three response alternatives were mapped to the left arrow key, down arrow key, and right arrow key, respectively.

(2) Color monitoring test （Updating task): Participants were shown blue, yellow and red circles (8cm in diameter) one at a time for 500ms in randomized order with an inter-stimulus interval of 2500ms. The task was to respond when the third instance of each circle color was presented (e.g., after seeing the third blue circle, or the third yellow circle), which required participants to monitor and keep track of the number of times each color had been presented. For example, if the sequence was ''blue, red, yellow, yellow, red, blue, *yellow, blue, red*'' then the participant should have responded to the third blue, yellow and red circle (italicized). In order for momentary mental lapses to have less impact on task performance, the circle count for each color was automatically reset to 0 if the participant made a key press for that color, and participants were informed of this feature before starting the task. Prior to completing the trial blocks, participants received a practice session, which continued until they made 3 correct responses.

(3) Wisconsin Card Sort Test (WCST; Shifting task): In this task, four stimulus cards were presented to participants. The objects on the cards could differ in color, quantity, and shape. The participants were then given an additional card and were asked to choose which one of the four original cards conformed to the same category as the additional card. As the classification rule was not provided to the participants, they had to guess the rule. They did this based on the pattern of feedback provided to them ("correct" or "incorrect"), after they chose one of the four cards to match with the additional card. In this experiment, the classification rule changed after 10 correct responses under the rule. The task was finished when a participant completed 8 different rules or 128 trials, whichever came earlier. We used the number of perseveration errors as the performance measure based on previous research [17].

4.1.3 Results

Data from six of the participants was removed from the analysis because of problems in collecting their data (e.g., failing to follow instructions). The skill levels of the remaining 96 participants were then assigned into three categories on each of the three executive functions (inhibition, updating, and shifting) using the following method. Measures obtained on the experimental tasks that corresponded to each of the three executive functions were characterized as low (-1), medium (0) and high (1) by segmenting the standardized (z-) scores obtained on each measure across the entire sample of participants. A z-score of less than -1 was interpreted as low ability (relative to the rest of the sample), a z-score between -1 and 1 was interpreted as medium ability, and a z-score of greater than +1 was interpreted as high ability. This created three variables that represented the three skill levels (high, medium, and low).

Table 1 CE ability patterns

	CE ability			Number of participants		
Group	Inhibition	Shifting	Updating	screening test	main experiment	
average	0	0	0	33	7	
high inhibition	1	0	0	6	5	
low inhibition	-1	0	0	2	0	
high shifting	0	1	0	12	7	
low shifting	0	-1	0	5	3	
high updating	0	0	1	4	3	
low updating	0	0	-1	4	2	
mixed	-1	-1	0	30	7	(4)
	0	-1	1			(1)
	1	-1	1			(1)
	-1	-1	1			(1)
			Total	96	34	

Table 1 shows the results of CE ability patterns and the number of participants who are classified into the patterns.

5. EXPERIMENT

5.1 Method

5.1.1 Participant

Thirty-four people were selected from the screening sample for the main experiment . The people selected represented a variety of different profiles in terms of shifting, updating, and inhibition ability (however, one limitation was that neither of the two "low inhibition" people could participate in the main test). The people who participated in the main experiment consisted of 20 males and 14 females, aged from 17 to 64 years old (M=42.9, SD=13.2). The numbers of each cognitive pattern are shown in Table 1.

5.1.2 Primary tasks (driving-related tasks)

We selected two types of tasks, which we assume to be related to fundamental aspects of driving.

(1) Detect-respond task

This target detection task was designed to simulate a situation to detect a particular road sign or sudden obstacles while driving and to respond to it. The task consists of two blocks. In the first block (easy block), either a red, down-pointing triangle (r=20 pixels) or a gray circle was presented on the main display for 1500 ms (Figure 2). Participants were instructed to tap a pedal with their right foot immediately after (and not until) they saw a red triangle. The study used six different inter-trial time intervals (750, 1250, 1750, 2250, 2750, 3250 ms) between the end of one trial (when the participant pushed the foot pedal to make his or her response) and the display of the stimulus for the next trial. Both the length of inter-trial intervals and the position that objects appeared in were varied randomly across trials. There was a 1/2 chance on each trial of getting either stimulus (a red triangle or gray circle) and a 1/6 chance of being assigned a specific inter-trial interval. In the second (more difficult) block, stimuli included a red triangle, red circle, gray triangle or gray circle (i.e., there were three distractors, and the target was defined by the conjunction of two features).

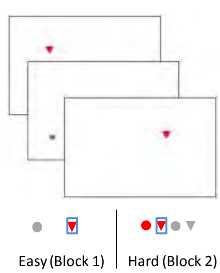

Figure 2 Detect-respond task

(2) Pedal tracking task

This task was designed to simulate performance of keeping inter-vehicle distance. We chose this task based on a pedal tracking task used by [26]. Our implementation of the task was designed to function like an inter-vehicle distance keeping task. A target rectangle in blue (corresponds to a car in front) and a frame-shaped area in yellow were displayed on the main display (Figure 3). The participants' goal was to keep the outer edge of the target rectangle inside the yellow area by controlling a foot pedal.

To simulate adjust inter-vehicle distance controlling an acceleration pedal, The size (side length) of the target rectangle (D) was defined by the equation (1).

$$\boldsymbol{D = D_0 + \left(V_0 + \left(S_f - L_T\right) dt\right) dt} \qquad (1)$$

Initially D_0 was equal to half the width of the acceptable area (yellow area), V_0 equaled 0 km/h and dt was 0.1sec. S_f represented the fluctuating signal while L_t was a percentage of the first order lag of the throttle opening. D was the second-order integral of the difference between the fluctuating signal (corresponding to the acceleration of the car in front) and the control signal (corresponding to the acceleration of one's own car; the first order lag of the throttle opening %). The fluctuation signal was generated from a mixture of four sine waves.

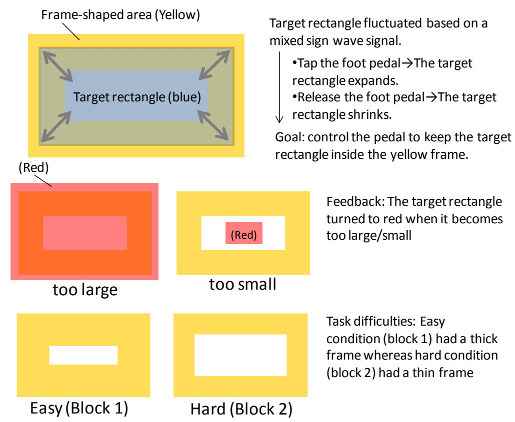

Figure 3 Pedal tracking task

5.1.2.1 Secondary tasks (CE tasks)

We developed inhibition, shifting, and updating tasks in both visual and audio conditions. We also prepared a simple key press task as a control condition (Table 2).

(1) Visual Inhibition (VI)

We used the Stroop task from the screening test as a visual inhibition task. Accuracy and RT were used as the performance measures.

(2) Audio Inhibition (AS)

We used a modified auditory Stroop task based on previous research [5][19][22]. Three different words ("High", "Day", "Low") were presented individually in two pitches (High pitch: 290Hz, Low pitch: 110 Hz) with semi-random word-pitch combinations (the numbers of each combination of word-pitch was balanced). The participant's task was to indicate the pitch by pressing a corresponding key (low = left arrow, high = right arrow).

(3) Visual Shifting (VS)

We wanted to have equivalent shifting tasks in both visual and audio conditions. However, since it was difficult to utilize the WCST in an audio condition, we developed a new task that required rule shifting.

A single digit number (the target number, varying between 1 and 8) was presented on a display with three single digit numbers (the option numbers, between 0 and 9) underneath it. The option numbers represented (a) the sum of the target number plus 1, (b) the decrement of the target number minus 1, and (c) the same number as the target number (i.e., plus 0). Participants were expected to apply one of the rules (+1, -1, 0) to the target number, and then indicate the result by pressing a key that corresponded with the position of the desired option number (the right arrow for the option displayed on the right, the left arrow for the option on the left, and the down arrow for the option presented in the middle. The horizontal ordering of potential responses (-1, 0, +1) presented along the bottom of the screen changed randomly between trials. At the start of the task participants were told to simply guess the rule. After the system provided subsequent feedback as to whether the rule they applied was the correct (expected) one or not (a red "X" for incorrect responses), participants were instructed to find the expected rule as quickly as possible and to apply the same rule until it changed. After eight consecutive correct responses, the program changed the rule.

(4) Audio Shifting (AS)

The procedure in this task was equivalent to the Visual Shifting task except that all the stimuli were presented in audio; A single digit number (1-8; the target number) was presented in a high-pitched voice (290Hz) followed by three single digit number (0-9) in low-pitch voice (110Hz) as options. Feedback to an incorrect response was given using a beep sound. The three option numbers corresponded to the left, down and right arrow keys, in that order.

(5) Visual Updating (VU)

The procedure in this task was similar to that used in the updating task during the screening study. However, in this condition we used two colored circles instead of 3, and the participants were instructed to respond to the second blue and second yellow circle. This visual version of the task was equivalent to the Audio Updating task except that all stimuli were presented visually.

(6) Audio Updating (AU)

For this task we used the modified procedure based on Miyake et al. [17] which was modeled on the Mental Counters task developed by Larson et al. [10]. Participants were presented with high-pitched tones (880Hz) and low-pitched tones (220Hz) for 500ms, with an inter-stimulus interval of 2500ms. This procedure was essentially a repetition of the visual updating tasks used in screening and in the VU condition except that two tones were used in place of two colored circles: Participants responded to the second occurrence of any given tone.

(7) Simple key press task (SK, control condition)

In this task, one of the words "Left", "Down" or "Right" was presented on the secondary display. The participant's task was to press the key that corresponded to the word (Left = left arrow, Down = down arrow, right = right arrow). This task was designed to require roughly equivalent visual and manual workload to the other CE tasks, so that the effect of cognitive workload could be assessed.

Table 2 CE task conditions

	Inhibition	Shifting	Updating	Simple Key press (Control)
Visual	(VI) Stroop task Black	(VS) Number calculation rule task 5 5 6 4	(VU) Color monitoring task	(SK) Press left, down or right arrow key corresponding to the instructed direction. Left
Audio	(AI) Auditory stroop task "High" "Low""Day"in high/low pitch	(AS) Auditory number calculation rule task	(AU) Tone monitoring task	

5.1.3 *Apparatus*

The main and CE task programs were run on the same computer, and were shown on the main display and secondary display correspondingly. Experimental equipment was set up as shown in Figure 4. Table 3 shows information concerning the manufacturers and models of the equipment.

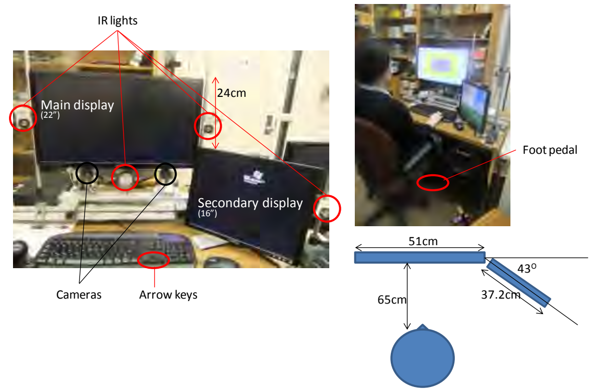

Figure 4 Experiment settings

To measure the participants' eye gaze information, a two-camera Remote Eye-Gaze Estimation (REGT) system (VISION 2020-RB, El-MAR Inc., [4]) was used. The system consists of two cameras (1624 x 1224 pixels) and four infrared light-emitting diodes (LEDs) mounted to either side of the camera (Figure 4).

Table 3 Equipment used in the experiment

		Manufacturer/model
Main display (23" LCD)		Acer/ 23"/58cm Wide LCD Monitor, S231HL
Secondary display (17" TFT)		Dell/ E177FPf TFT, E177FPf
Foot pedal		Logitech/ Driving Force GT
PC	OS	Microsoft/ Windows XP Professional
	Motherboard	Gigabyte Technology Co., Ltd./ X58A-UD3R

5.1.4 *Procedure*

All experimental sessions were conducted at the University of Toronto from January through March 2012. Participants participated in the experiment individually.

The participants performed one of the two driving-related tasks as a single task. They then performed the driving-related task and CE tasks as dual tasks. The CE tasks consisted of the six CE function conditions (AI, VI, AS, VS, AU, VU) and a Simple Key press (SK) condition. The order of the CE task was varied among participants in order to avoid order effects. After a 5-10 minute break following the first driving-related task condition (performed as a dual task with each of the CE tasks), participants then performed the second driving-related task condition with the same seven CE tasks. Each participant was exposed to all 14 dual task conditions (one CE task at a time), with approximately two minutes' worth of trials per condition. Ordering of conditions was counterbalanced between participants. Participants were instructed to respond as quickly and accurately as they could, and to allocate their attention in such a manner as to perform as well as they could on both of the tasks. Participants were paid for their participation and signed a consent form before participating, in accordance with a research protocol that was approved by the University of Toronto Ethics Review Board.

5.2 Results

5.2.1 *The effect of CE ability on the primary task performance under a particular CE loading condition*

(1) Detect-respond task

We calculated the median correct response times by participant and condition, and compared them between different CE ability groups. Medians, rather than means, were used as measures of central location as they are robust to the effects of positive skew that typically occur in distributions of response time measures, and that was also present in our data. Regression analyses were then carried out to assess the degree to which high CE workload affected detect-respond response times in the presence of CE loading tasks. Both backward and forward methods of entry were used on all the regression analyses reported below. However, since the results for forward and backward entry were similar in all cases, only the backward entry results are reported below.

For analysis of the detect-respond task data, seven backward entry stepwise regression analyses were carried out with response time on the detect-respond task as the dependent measure. One analysis was carried out for the SK condition, and three analyses each were carried out for the inhibition and shifting conditions respectively. These three analyses consisted of one for block one, one for block two, and one where the slowing in detect-respond time between block1 and block2 was used as the dependent measure. The predictor variables in each of these analyses were six measures of CE ability measured in the screening test. The variables and results are summarized in Table 4.

For the block 1 in AI condition, the best fitting model (p<.01) contained one predictor variable (inhibition correct RT) that explained 25% (r=.503) of the variance in detect-respond response time. The best fitting model for the block 2 (p<.05) was also inhibition correct RT as a single predictor, in this case explaining 16% of the variance (r=.401). No model was found that predicted the slowing (due to the added difficulty of two extra distractors in the detect-respond task) between block 1 and 2.

For the block 1 in AS condition, the best fitting model (p<.05) contained inhibition correct RT and WCST perseveration errors, which jointly explained 22% (r=.466) of the variance in detect-respond response time. The best fitting model for the block 2 in AS (p<.05) was a single measure of shifting ability, WCST rules completed, in this case explaining 30% of the variance (r=.544). No model was found that predicted the slowing between block 1 and block 2 of the detect respond task.

For the block 1 in AU condition, the best fitting model (p<.05) contained inhibition correct RT, inhibition accuracy and WCST perseveration errors, which jointly explained 28% (r=.524) of the variance in detect-respond response time. There was no significant predictive model for the block 2 data. However, a single variable model involving inhibition accuracy significantly predicted (p<.05) the slowing between block 1 and block 2 of the detect respond task, explaining 14% of the variance (r=.367).

For the SK task the best fitting model (p<.05) again contained only the inhibition correct RT measure, which explained 13% (r=.366) of the variance in detect-respond response time.

For the block 1 in VI task the best fitting model (p<.001) contained four predictor variables (the two measures of inhibition CE ability plus the two measures of shifting CE ability) that jointly explained 85% (r=.919) of the variance in detect-respond response time. The best fitting model for the block 2 in VI (p<.001) included three predictors (the two measures of inhibition CE ability, plus the number of WCST perseveration errors), which explained 54% of the variance (r=.734). No model was found that predicted the slowing between block 1 and block 2 with the visual inhibition CE task.

For the block 1 in VS task the best fitting model (p<.001) contained three predictor variables representing each of the three CE abilities (inhibition correct RT, updating accuracy, and WCST perseveration errors) that explained 58% (r=.76) of the variance in detect-respond response time. The best fitting model for the block 2 in VS (p<.005) contained the same three predictors as had been found for block 1, in this case explaining 39% of the variance (r=.62). No model was found that predicted the slowing between block 1 and block 2.

For the VU task none of the predictive models were statistically significant either for block one or for block two data. As in most of the other CE task conditions, no model was found that significantly predicted the slowing between block 1 and block 2. The preceding results are summarized in the first two columns of Table 4, where each cell represents a regression analysis. Note that no significant predictors were found for the block 2 updating analyses.

Table 4 Significant Predictors of the Primary Task Performance by type of CE task CE Function loading

Secondary task \ Primary task		Detect-Respond Task		Pedal Tracking
		Block 1	Block 2	(No significant differences between blocks)
Auditory	Inhibition	I	I	U
	Shifting	I, S	S	I, S, U
	Updating	I, S		S, U
Visual	Inhibition	I, S	I, S	U
	Shifting	I, S, U	I, S, U	S, U
	Updating			S, U

●dependent variables
detect-respond task: reponse time (RT)
pedal tracking task: error rates (the proportion of the time that the target rectangle was out of the yellow allowable area)
●predictor variables (based on the screening test results)
inhibition (I) : correct RT and accuracy in Stroop test
shifting (S) : prseveration error rate and the number of rules completed in WCST
updating (U) : correct RT and accuracy in color monitoring test

(2) Pedal tracking task

We calculated the mean error rates (the proportion of the time that the target rectangle was out of the yellow allowable area) by participant and condition, and investigated which CE functions can be predictor of the error rates. As with the detect-respond task we ran a series of backward stepwise regression analyses examining which of the CE abilities predicted pedal tracking accuracy in the presence of the different CE task conditions. The results are summarized in the right-most column of Table 4. Note that the pedal tracking regression analyses were carried out with pooled data across both blocks because no significant differences were found between the blocks.

For tracking accuracy during the AI task as a secondary task, updating total accuracy was the only significant predictor (p<.005) explaining 30% of the variance (r=.547).

In the AS condition, tracking accuracy was predicted (p<.001) by a combination of the three CE abilities (inhibition accuracy, WCST completed, and updating total accuracy), with 48% of the variance explained (r=.689).

In the AU condition, only two of the CE abilities were represented in the best fitting (p<.005) model (WCST completed rules, and updating total accuracy), accounting for 38% of the variance in pedal tracking accuracy (r=.613).

In the SK condition, updating total accuracy (p<.001) was the sole predictor in the selected model explaining 34% of the variance (r=.583).

In the VI condition, updating total accuracy significantly predicted pedal tracking accuracy (p<.001), explaining 40% of the variance (r=.632).

In the VS condition, updating total accuracy and WCST jointly predicted the pedal tracking accuracy (p<.005), accounting for 38% of the variance (r=.614).

Finally, in the VU condition, updating total accuracy and WCST jointly predicted (p<.001 43% of the variance in pedal tracking accuracy (r=.658).

5.2.2 The effect of modality and task types

Based on the eye tracking data, we calculated the proportion of the time that participants viewed the main vs. the secondary task display (main display gaze rate). Figure 6 shows the main display gaze rate and detect-respond task performance (difference of correct response time between single and dual task; diffMedianHitRT).

In general, the main display gaze rate was higher in the audio vs. visual secondary task conditions (i.e., there was less visual distraction in the audio conditions). However, the VU condition showed a higher gaze rate on the main display (lower visual distraction) as compared to the other visual conditions. This may be because the task could be performed using peripheral vision, as was reported by some of the participants.

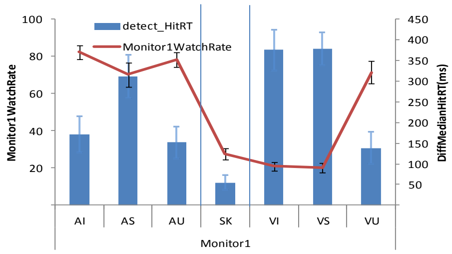

Figure 6. Main display gaze rate and the driving-related task performance (detect-respond task)

As shown in Figure 6, driving-related task performance was not impaired as much with the audio secondary tasks. The VI and VS conditions were visually distracting and results in a slowing of primary task performance. On the other hand, the VU secondary task resulted in less visual distraction and relatively little slowing in primary task performance relative to the single task condition. One other feature in Figure 6 is that the slowing in primary task performance with the AS secondary task was much higher than the other audio conditions and almost comparable with the VI and VS slowing. This suggests that the AS task was more cognitively distracting than the other audio secondary tasks.

5.3 Discussion

5.3.1 Individual CE abilities and driving-related task performance while performing the particular CE task as a secondary task

The results of the regression analysis did not support our hypothesis that the match between CE Function loading on a CE task and individual ability on that CE function predicts task performance on the driving-related task in a dual task setting. In other words, we could not find evidence that CE ability can be a predictor of the driving-related task performance under a particular CE loading condition.

On the contrary, we found (unexpectedly) a fairly consistent relationship between CE ability and primary task performance, regardless of which CE function was loaded by the secondary task.. The results showed that better inhibition and shifting abilities helped people perform better in the target detection task whereas in the pedal-tracking task, it was higher shifting and updating ability that led to better performance (Table 4).

These results suggest that shifting ability aids in managing dual tasks, whereas inhibition is required to deal with distraction in the detect-respond task. Additionally updating appears necessary to deal with distraction in the pedal tracking task.

The overall pattern of results showed a strong influence of cognitive distraction on the target detection and pedal tracking tasks, as indicated by the fact that people who had higher abilities on specific CE functions were able to perform better on the driving-related task when it was carried out in a dual task setting.

Why wasn't the relationship between ability on a particular CE function and primary task performance affected by a secondary task that loaded on that function? Two possible explanations are suggested below.

1. CE functioning changed in the dual task setting

Some previous research studies have argued that dual-task coordination is a separate component of CE function. When a task is performed in a dual-task setting, the function of dual-task coordination may become the most relevant, and strongly loaded, function. This might explain why shifting ability significantly predicted primary task performance in almost of all the dual task settings that we examined.

2. The secondary tasks we designed might not have been pure enough measures of the CE functions that we were trying to characterize.

In order to provide a equivalent rule-shifting task in both visual and audio conditions, we created a new shifting task based on the WCST. However, we observed that participants often needed to retain or retrieve the target number while performing this task. Thus it is likely that the task did not purely load on shifting function, but also loaded on memory retention/retrieval. Similar concerns might be raised about the updating and inhibition secondary tasks that were used in this study.

Thus it is possible that expected secondary task CE function loadings did not interact with ability on those function because participants were loaded on several CE functions during the dual-task, and not only the CE function targeted by the secondary task.

5.3.2 The effect of visual and cognitive workload

Comparison between visual and audio conditions showed that participants generally looked away from the main display for longer periods of time in visual vs. audio conditions, except for the VU condition, where participants seemed to use their peripheral vision. However, comparison between SK and other audio conditions showed that audio tasks with high cognitive loads had been slowed down more. This suggests that "audio UI with high cognitive load could be more distracting than visual UI with low cognitive load" . In this research, we used a single test to estimate each CE ability. However, due to the well-known test impurity problem (e.g. [21]), no test completely represents a particular CE ability. Thus it is recommended for further research to use multiple test batteries for each CE function to assess the common factors among the tasks.

6. CONCLUSIONS

We had expected that cognitive ability would affect the ability to perform a driving-related task in the presence of secondary tasks that loaded on activities requiring CE abilities and this was found to be generally true. With some exceptions people with higher cognitive abilities tended to have better performance, both on pedal tracking, and on the detect-respond task, in the presence of the CE loading secondary tasks. However, this affect of CE ability was more notable in the easier conditions of the detect-respond task, and generally did not affect the slowing that occurred when the detect-respond task was made more difficult in the second block through the addition of more distractors. Thus it appears that the benefits of higher cognitive ability are stronger in simpler versions of a primary task when performed in the presence of distracting tasks that load cognitive abilities. We also found evidence of a fair amount of interplay between the CE functions highlighted by the previous research [17] with performance in the presence of a distracting task representing one function sometimes being predicted by a combination of the CE abilities, or in some cases by a different CE ability.

Overall these results indicate that there is a role for detailed evaluation of CE abilities and their impact on distracted driving. However, the present results suggest that CE abilities play a larger role in simpler versions of primary tasks and that the mapping between the impact of CE abilities and the CE functions required in the distracting CE task is not a simple one.

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Real-time Assessment of Driver Cognitive Load as a prerequisite for the situation-aware Presentation Toolkit PresTK

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ABSTRACT

In this paper, we discuss the impact of cognitive load (CL) measuring to the design of In-Vehicle Information Systems (IVIS). Three ways of assessing CL known from literature are discussed in terms of their applicability to non-intrusive in-car applications. A fourth way to estimate CL is presented. We add some thoughts on estimating the complexity of presented information and combine it with the knowledge of the driver's CL and driver's user model to approaches for adapting the system to the driver's current mental state. Furthermore, we shortly introduce our currently developed presentation toolkit PresTK, which takes the discussed factors into consideration.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Applications**]: User Interfaces; H1.2 [**User/Machine Systems**]: Human factors—*complexity measures, performance measures*

General Terms

Theory

Keywords

cognitive load, presentation complexity, automotive information systems

1. INTRODUCTION

The rapid increase of complex information systems in our environment and especially in the car has raised the level of attention required from the user, i.e., the driver. In order to ensure the usefulness of information presented by an in-car Human Machine Interface (HMI), the question whether or not it can be adequately processed by the driver has to be asked. Similar to the specification of the hardware requirements for a certain piece of software, we will have to specify the cognitive requirements of processing a certain piece of information.

Figure 1: The Cognitive Load of the driver can be used for adapting the User Interface

In a situation with high cognitive demand, information presentation could for instance be simplified by removing less relevant information to ensure that the driver registers all important facts.

Although the definitions of Cognitive Load (sometimes also called mental workload or cognitive workload) slightly differ from each other, they are typically similar to Wickens' definition as "the relationship between the cognitive demands of a task and the cognitive resources of the user" [23]. A more detailed definition is given by [3]: "the demands placed on a person's working memory by (a) the main task that she is currently performing, (b) any other task(s) she may be performing concurrently, and (c) distracting aspects of the situation in which she finds herself". [4] provides a survey of alternate definitions.

Traditionally, workload assessment techniques are divided in three groups: subjective measures (questionnaire based, self-reported), performance-based measures, and physiological measures. By widening the scope of assessment beyond actual measuring, we might add a fourth category of deducting cognitive workload from the environment.

Figure 1 shows the connection between the situation/context, the drivers cognitive workload and his driving performance. As we can see, the presentation manager acts as a link in a feedback loop, regulating indirectly the CL by adapting the HMI. This is assisted by presentation complexity estimation. In this paper, we discuss the implications for designing in-car HMIs as a prerequisite for the currently developed presentation toolkit PresTK [9], which tackles the orchestration of mutually independent information sources.

2. COGNITIVE LOAD ASSESSMENT

Knowing the current cognitive state (here: CL) of the driver is very useful for adapting the HMI according to his needs. As a first step, we need to make sure that the measurement reflects reality as close as possible in order to reliably utilize it later on. In this section, we discuss several ways of CL assessment in respect to their usefulness in in-car applications and their feasibility for non-intrusive measuring while driving.

2.1 Subjective measures

A simple and reliable way to assess a subject's workload is self-reporting, assuming that the person is cooperative and capable of introspection and reporting their perceived workload, either directly or by answering questions resulting in a measure. Commonly, questionnaires for self-reporting workload refer to a task already performed. One of the most widely known methods here is the NASA Task Load Index (NASA-TLX). Self-reporting of workload usually covers a single task and cannot be used without extension or modification to report on a complex situation involving several, potentially overlapping tasks. Furthermore, applying questionnaires is an intrusive procedure (adding another task to the subjects working memory) and can only be done after the task being performed. Although some tests are intended to be administered "online" right after performing the task, the test might interfere with the performance in subsequential tasks. Furthermore, none of the online questionnaires are designed for real-time assessment.

It is important to keep in mind that most of these questionnaires are not designed for automotive applications, and not all of them measure the same dimensions–if they are multidimensional at all. Dimensions necessary in the driving context are detailed in [9].

The NASA Task Load Index (NASA-TLX), for instance, which was developed in a "multi-year research effort aimed at empirically isolating the factors that are relevant to subjective experiences of workload" [14] was originally intended for crew complement in the aviation domain. Since its introduction in the mid-eighties, it has spread significantly beyond the original application, focus and language [13]. It is designed as a short questionnaire with 6 questions to be answered on a 21 point scale. The result of the test after a complex evaluation is a multidimensional numerical value on six subscales, only one of them being mental demand.

The Bedford Scale [6] uses a completely different approach. It is a uni-dimensional rating scale designed to "identify operator's spare mental capacity while completing a task". It uses a hierarchical decision tree guiding the user to a rating scale value between one and ten. It is an obvious advantage of the process that in each step of the decision tree the symptoms of having exactly that level of workload are verbally described. This prevents the user from a natural tendency to avoid the extreme values of the scale, even if appropriate.

The Subjective WORkload Dominance (SWORD) technique, as another example, is based on mutual comparison between tasks [22]. The user rates all possible pairs of given tasks in mutual comparison on a scale. A judgment matrix is then calculated based on this data. If this matrix is consistent, relative ratings of each task can be determined.

Figure 2: Connection between situation, cognitive load and driving performance

2.2 Performance based measures

Assuming that an increased CL diminishes human performance, we can use performance measures as an indicator of actual workload. This assumption is backed by the Yerkes-Dodson-Law [24], which is based on an experiment with electric shocks on laboratory mice. Unfortunately, this law has some serious gaps: 1. The methods of calibrating electricity were too crude for exact measurements, 2. the implicit underlying assumption of a linear dependency between stimulus and level of arousal was never validated, and 3. the connection between the behaviour of mice and human beings was just implicitly assumed. Despite these flaws, the use of the Yerkes-Dodson-Law has been established as a valid method [20].

The basic statement is–rephrased for our domain–that the driver's performance is best at a medium level of arousal / workload, i.e., he should neither be bored nor overwhelmed. [12] also examined the impact of cognitive distraction and showed that it has a negative influence on driving performance and safety, especially on the driver's visual behavior. Two approaches of performance measures are feasible in an automotive environment: measuring the driving performance and measuring the reaction time to events such as displayed information or events outside the car.

Driving performance

Recent literature on measuring the drivers CL strongly emphasizes the role of speed and steering wheel angle and their respective change over time. This is very convenient, since this information is easily acquired using the car's CAN-bus. [16] built a prototype to estimate driver distraction in a simulator based on a Fast Fourier Transformation (FFT) of the steering wheel angle. [21] use an artificial neural network (NN) to determine the driver's current level of distraction. Using a three layered Multi-Layer-Perceptron, a single numerical value as the level of distraction ranging from one to five is deducted from four input variables: speed, speed variation, steering wheel angle and steering wheel angle variation. An adaptive system taking driver distraction into consideration was evaluated as being superior in terms of perceived safety and usability to the non-adaptive version. Models based on neural networks have proven successful previously, e.g. [1]. [19] estimates CL complexity using both performance and physiological data in a simulator. As performance measures, the lateral position variation and steering wheel activity is observed. That data is then fed into a radial-basis probabilistic neural network (RBPNN).

Reaction time and time perception

Reaction time is a convenient way of measuring performance. [17] clearly shows a direct impact of driver and situational factors on break reaction time (BRT) and acceleration / deceleration reaction time (ADRT). [5] measured the impact of distraction by mobile phones on the driver's reaction time. Many other examples can be found in literature.

As another interesting aspect, CL seems to directly influence the perception of time. In a user study, [2] measured the difference between time intervals produced by a driver in different situations and compared the mean deviation from the actual time with the CL of the driver measured by other means. Results show a direct connection, i.e., perceived time correlates with actual cognitive workload.

2.3 Physiological measures

Although usually used in medical research and examination for obtaining information of state and performance of major organs, we can also use physiological sensors for obtaining information about the state of the subject. Most suitable for our purpose are obviously parameters which can not consciously be modified. For our purpose, it is important to find a completely non-intrusive method of measuring. Even small intrusion–like placing a sensor on a finger–which is easily accepted in a user study, is unlikely to find acceptance by the driver in every day driving.

Measures known from literature include respiration, skin conductance, temperature, eye movement, pupil diameter, and voice analysis. Only the last three of those can be measured in an unintrusive way, but the analysis of the data can get quite complex. [8] discusses the different methods in detail.

3. COGNITIVE LOAD BY CONTEXT

As we discussed in the previous section, applying traditional CL measuring techniques is not always desirable in our domain. Important features are real-time conduction, immediate availability of results (e.g. results do not have to be entered manually in the system), and unintrusiveness. Table 1 compares the advantages and disadvantages of different approaches.

Measure	Real-Time	Immediate	Intrusive
Subjective	- -	-	- -
Performance	++	+	++
Physiological	++	++	- -

Table 1: Suitability of cognitive load assessment for real time automotive applications is limited.

As shown in Figure 2, current CL might also be estimated using another path, i.e. by assessing the impact of the environment on the driver. Although the context might not be sufficient for an exact estimate of the driver's state, we can safely assume some factors to be influential to his cognitive demands. Driving on the highway or in dense city traffic is probably more demanding than driving on a quiet rural road. Driving at a moderate speed is less stressful than driving at very high speed or being stuck in a traffic jam. Also, environmental conditions such as noise level inside and outside the car can be measured and considered. The cars built-in information systems can keep a history of information presented to the driver, from which we can conduct the cognitive demand. A lot of information flooding the driver in a very short period of time is likely to raise his CL.

[18] used Dynamic Bayesian Networks (DBNs) and data obtained from the car directly to generate a continuous estimate of the drivers load. In a second step, the DBNs were transformed into arithmetic circuits for efficiency reasons, especially considering the usually limited computing power of a vehicle. This concept could be adapted and extended to other information sources in order to increase the quality of the estimate.

In our current research, we examine the impact of visual environmental complexity and speed on the driver's cognitive load in a simulator experiment [11].

Figure 3: A Presentation manager aware of the current cognitive load of the driver can positively influence driving performance

4. ESTIMATING COMPLEXITY

In order to assess system-generated CL, we need to be aware of the impact of system-generated presentations to the driver, i.e. estimate presentation complexity. The approach for answering this question is depending on availability of structured data. We distinguish three different cases:

1. Structured information about presentations is available as a blueprint in the system. In that case, experts can analyze and annotate this information. This enables us to choose the most appropriate presentation type at runtime.

2. When obtaining structured presentations at runtime, we can analyze for instance linguistic complexity, amount of information pieces, font size, complexity of icons and graphics, and other factors. [7] for instance presented a measure for linguistic complexity, which could be used both for analyzing textual on-screen presentation as well as for estimating the complexity of synthesized speech output. Similar measures can be found in literature. [15] provides a very detailed survey and quantitative analysis on the impact of parameters such as font size and contrast on the average glance time of the driver. We propose a layout-based procedure to combine previous research results in [10].

3. We obtain an unstructured presentation in form of an image or an audio file, or both. Chances of making a very good analysis of its complexity in real time are not very good then, but we might be able to give a rough estimate based on formal parameters described in case 2.

5. IMPLICATIONS FOR IVIS

How can we adequately utilize the previously collected information? Figure 3 shows the impact of a presentation manager to the driver's CL. By assessing both information complexity as well as measuring CL, presentations can be modified such that in high demand situations the additional cognitive workload is kept at a minimum. Complex presentations can be avoided or replaced by presentations with a simplified version of the same content, or, in case of low priority, skipped altogether. If complex presentations have to be presented, we can make sure that the time for processing them is sufficiently long. If new and potentially difficult

Figure 4: The presentation toolkit PresTK considers drivers cognitive load and information complexity.

to grasp graphical concepts are used in the HMI, we may consider introducing them in low demand times and only use them as well in high demand times after we can assume the driver's familiarity. Another aspect to be considered is the individual's cognitive capacity. Determining factors are (among others) age, experience and skills.

6. THE PRESTK TOOLKIT

The context of the research presented in this paper is the currently developped presentation toolkit PresTK [9]. Its architecture (see figure 4) reflects both the dynamic nature of the driving environment as well as the double restriction of available resources: There are technical restrictions, e.g., the available space for presenting information is limited, which is followed up by the cognitive limitation of the driver. By both analysing the complexity of the presented information as well as monitoring the current cognitive load of the driver, presented information can be adapted in the scheduling process and be filtered in high demand times.
The toolkit is designed with the automotive domain in mind, but can be used more generally for similar problems as well. By using a component-based structre, we add flexibility to customize several components, the selection of components used, and thus the architecture required in general.

7. CONCLUSIONS

Real-time assessment of the drivers state, especially his CL, is an important factor for adapting IVIS and making the flow of necessary information more efficient without overwhelming the driver. As a foundation, we need a combination of either measuring or estimating CL with an approximate quantification of the complexity of the information presented. The resulting system serves as a regulatory circuit between HMI, driving performance, and CL. Individual need for adaptation may vary among drivers, depending on their cognitive capacity. We discussed the options for necessary building blocks and their suitability for this endeavor in this paper. The concepts presented in this paper provide a part of the foundation for the development of the presentation toolkit PresTK.

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Sensitivity of Multiple Cognitive Workload Measures: A Field Study Considering Environmental Factors

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ABSTRACT
Objective: This paper aims to compare the sensitivity of multimodal cognitive workload measures for classifying a driver's cognitive demand level from on-road experimental data. The measurement domains consist of driving performance, physiological arousal and eye behavioral change. **Method:** subjects (15 males in the 25-35 age range (M=27.9, SD=3.13)), experimental setup (an instrumented vehicle which consists of six video cameras, driving data logger, gaze tracker, and physiological measurement systems), procedure (20 minutes of driving exercise on a urban road and another 20 minutes of highway driving on 36km of highway), cognitive load (N-back task, an auditory delayed digit recall task was used to create periods of cognitive demand at three distinct levels), rating of driving workload (rating subjective driving workload after watching the experimental video clips by 4 different reviewers). **Result:** Potential measures of driver's cognitive workload are suggested to estimate drivers' cognitive demand level. It is expected that these measures can be used for evaluating the design of in-vehicle interface objectively.

Categories and Subject Descriptors
J.4 [Social and Behavioral Sciences]

General Terms
Human Factors

Keywords
Cognitive Workload Metrics Sensitivity, Driving Performance, Physiology, Eye Behavior, Driving Workload

1. INTRODUCTION
In recent years, a large number of researchers have been devoted to investigating the effect of cognitive workload on driving performance [1-2], physiological response [3-4], and eye behavior [5-6]. However, it is know that there is no simple measure to index cognitive workload because the driver's mental status is not observable, and each of these methods provides advantages and disadvantages depending on the setting and measurement goal. Among those measurement domains, driving performance measures can detect the cognitive workload using easy and less expensive methods, but have limitations compared to others due to small changes according to the cognitive workload [2]. For the physiological measures, several driving research projects were examining physiological measures as indicators of workload during driving. Most recently, Mehler et al. found that both heart rate and skin conductance were sensitive physiological measures for detecting systematic variations in cognitive demand [3]. These findings are different from the results of the HASTE project that show inconsistent relationships between heart period, skin conductance, and demand level in both auditory and visual tasks and do not suggest any consistently sensitive physiological measures for differentiating cognitive demand levels [4]. In the eye behavioral measures, Reimer et al. reported that horizontal gaze concentration under systematically added cognitive demand, which was loaded by the same surrogate secondary task as that of Mehler's study, increases in a relatively linear fashion [5]. However, the results of the HASTE project suggested that significant gaze concentration caused by the auditory task in comparison with baseline but they do not show significant increase in gaze concentration between tasks [6].

In order to clarify those conflicted findings, this field study aims for replicating systematically added cognitive demand method in a different setting and comparing the sensitivity of multiple cognitive measures for differentiating four levels of cognitive demand from a working memory task. In addition, this study evaluates the primary driving workload rates [7] to consider the influence of environmental factors when comparing these results with other field studies.

2. METHOD

2.1 Field Study with Cognitive Load

2.1.1 Subject
Subjects were required to meet the following criteria: age between 25-35, drive on average more than twice a week, be in self-reported good health and free from major medical conditions, not take medications for psychiatric disorders, score 25 or greater on the mini mental status exam to establish reasonable cognitive capacity and situational awareness. The subjects consisted of 15 young males (M=27.9, SD=3.13).

2.1.2 Experimental setup
The experiments were conducted in a full size sedan that is instrumented for collecting time-synchronized data. The DGIST instrumented vehicle consists of six video cameras (two for driver and four for road environment monitoring), high speed and low speed CAN logger, driver gaze tracking system, and physiological measurement system. The DGIST-designed custom monitoring software was separately running on four windows-based PCs and synchronized by storing the measurement data with master time that was sent by a main control PC.

2.1.3 Cognitive workload

An auditory delayed digit recall task, so called n-back task was selected to create periods of cognitive demand at three different levels. This form of n-back task requires participants to say out loud the nth stimulus back in a sequence that is presented via audio recording [5]. The lowest level n-back task is the 0-back where the participant is to immediately repeat out loud the last item presented. At the moderate level (1-back), the next-to-last stimulus is to be repeated. At the most difficult level (2-back), the second-to-the-last stimulus is to be repeated. The n-back was administered as a series of 30-second trials consisting of 10 single digit numbers (0-9) presented in a randomized order at an inter-stimulus interval of 2.1 seconds. Each task period consisted of a set of four trials at a defined level of difficulty resulting in demand periods that were each two minutes long. The n-back task was pre-trained until the participants met minimum performance criteria (No error for 0-back, not more than two errors for 1-back, and not more than three errors for 2-back). This n-back task procedure replicated the method of earlier studies [3], [5].

2.1.4 Procedure

Following informed consent, physiological sensor attachment and completion of a pre-experimental questionnaire about safe driving (safety protocol), participants were trained in the n-back task until they met minimum performance. Each participant's baseline performance on the n-back was subsequently assessed at each of the three demand levels with 2-minute breaks between each level. Then, participants received about 20 minutes of urban road driving experience and adaptation time on the instrumented vehicle. The highway driving experiment begins when a subject is confident in safe driving with the instrumented vehicle. In a main experiment session, participants drove in good weather through 36km of highway for about 20 minutes. The driving road has speed limit of 100kph, two lanes in each way, and about 8km of uphill and downhill (3~5 percent slope). The time between 5 and 7 minutes was used as a single task driving reference (baseline). Thirty seconds later, 18 seconds of instructions introduced the task (0, 1 or 2-back). Each n-back period was 2 minutes in duration (four 30-second trials). Two-minute rest periods were provided before presenting instructions for the next task. Presentation order of the three levels of task difficulty was randomized across participants.

2.2 Ratings of Driving Workload

In order to screen participants who were highly influenced by environmental factors during performing n-back task, subjective driving workload rates were evaluated as follows. Four reviewers, who did not participate in the field study, rated the primary driving workload after watching forward view video clips. Two pairs of reviewers were seated in two different driving simulators; one is on a driver seat and the other on a passenger seat. The five 2-minute video clips, including baseline, three n-back tasks and recovery periods, were displayed on two 2.5m by 2.5m wall-mounted screens at a resolution of 1024 x 768. Each video clip was played, paused, and resumed at every 10 seconds for rating the twelve ten-second segments. For reminding the base score of driving workload, two workload anchor pictures that indicated 2 and 6 were located on the dashboard.

2.3 Dependent Variables

2.3.1 Secondary Task Performance Measures

Error rates (ER) on the n-back were used to confirm the extent to which different conditions represented periods of higher cognitive workload. The error rate is a percentage of the times when subjects answer wrong numbers or give no answer to the numbers presented to them during the n-back experiment. It can be assumed that a higher error rate indicates higher cognitive load.

2.3.2 Driving Performance Measures

Longitudinal and lateral control ability was considered as driving performance measures for indicating the difficult level of cognitive workload. In order to assess the longitudinal control performance, mean speed (SPD) and speed variability that is expressed as the standard deviation of speed (SDSPD) were selected, because some drivers have been observed performing compensatory behaviors, e.g., reducing their speed to manage the increasing workload [8]. For the lateral control ability, steering wheel reversal rate (SRR) were selected. SRR was calculated by counting the number of steering wheel reversal from the 2Hz low pass filtered steering wheel angle data per minute. Due to the factor that cognitive secondary tasks yield increased steering activity, mainly in smaller steering wheel movements, the fine reversal angles, which have more than 0.1 degree of the gap size, were counted. Although the standard deviation of lane position (SDLP) is one of the most frequently used driving performance measure, it was not used in this study due to a technical problem.

2.3.3 Physiological Measures

As shown in Table 1, six physiological measures that consist of three cardiovascular activity-based and three electrodermal activity-based measures were used. For the cardiovascular measures, mean heart rate, heart rate variation, and delta HR were considered. Mean heart rate (HR) was calculated by inverting Inter-Beat Interval (IBI) that was computed using the Librow's R-peaks detection algorithm (Librow^{TM}, Ukraine). Heart rate variation, which was calculated by standard deviation of heart rate (SDHR), was considered because variation in the inter-beat interval is a physiological phenomenon under different cognitive workload. In order to reduce individual differences, delta HR (ΔHR), which was calculated by subtracting baseline heart rate, was used. For the electrodermal measures, Skin Conductance Level (SCL) was measured with a constant current configuration and non-polarizing, low-impedance gold-plated electrodes. Sensors were placed on the underside of the outer flange of the middle fingers of the non-dominant hand without gel. Average, standard deviation, and delta SCL was calculated from the measured SCL values.

2.3.4 Eye Behavior Measures

Cognitive workload can be identified through changes in eye behaviors, for example, blink rates, pupil diameter, dwell times, characteristics of saccadic movements, and the size of the visual field. This study considered five eye behavior measures including mean and standard deviation of horizontal and vertical gaze (HG, VG, SDHG, SDVG) and blink frequency (BF). Before calculating eye-movement measures, raw gaze data were filtered with the following criteria [5]: 1) the FaceLAB's automated gaze quality index for the left and right eyes was categorized as optimal, 2) the x-axis position was between -1.5m and +1.5m, the y-axis position was between -1.0m and +1.0m, and 3) the data point was contained within a set of six valid measurements. For the eye blink frequency (BF), raw data of each period were used for calculating mean values.

2.4 Data Analysis

Statistical comparisons of the objective measures were computed using SPSS version 17. Comparisons were made using a repeated-measures general linear model (GLM) procedure. A Greenhouse-

TABLE 1 Comparison of the Sensitivity of Cognitive Workload Measures

Methods	Measures	Descriptions	Mean (S.D.)					Main Effect	Pair-wise Significance						
			Baseline	0-Back	1-Back	2-Back	Recovery		BL-2B	BL-1B	BL-0B	0B-1B	1B-2B	RC-BL	RC-0B
Secondary Task	ER(single)	Error rate of secondary task scores (%)		0.00(0.00)	0.74(1.96)	3.33(6.52)		0.111				0.164	0.184		
	ER(dual)			0.00(0.00)	1.30(2.07)	4.79(7.91)		**0.049**				**0.029**	0.097		
Driving Performance	SPD	Mean speed (kph)	98.47(6.91)	95.44(6.88)	94.41(4.83)	93.07(7.86)	98.18(7.79)	**0.012**	**0.006**	**0.009**	0.084	0.533	0.444	0.416	0.106
	SDSPD	Standard deviation of speed (kph)	6.03(1.93)	5.33(2.35)	5.95(2.11)	4.79(2.25)	5.57(2.94)	0.479	0.126	0.919	0.353	0.482	0.135	0.538	0.767
	SRR	Steering wheel reversal rate (rev. counts/min)	63.88(11.11)	62.85(11.20)	65.98(13.02)	67.76(14.33)	59.85(13.26)	**0.012**	**0.095**	0.170	0.409	0.980	0.436	0.078	0.202
	MSRR	Modified SRR with adjusted baseline	59.85(13.26)	62.85(11.20)	65.98(13.02)	67.76(14.33)	59.85(13.26)	**0.010**	**0.018**	**0.004**	0.202	0.980	0.436	0.078	0.409
Physiology	HR	Mean heart rate (beats/min)	81.33(8.47)	84.26(8.55)	85.03(8.95)	88.83(9.28)	81.32(8.61)	**0.003**	**0.004**	**0.006**	**0.001**	0.319	**0.012**	0.985	**0.001**
	SDHR	Standard deviation of heart rate (beats/min)	3.71(1.01)	4.03(1.52)	4.55(1.92)	5.25(2.28)	3.74(1.02)	**0.047**	**0.025**	0.117	0.408	0.064	0.066	0.956	0.609
	ΔHR	Heart rate difference (beats/min)	0.00(0.00)	2.93(2.19)	3.70(3.79)	7.50(7.24)	0.00(1.83)	**0.003**	**0.004**	**0.006**	**0.001**	0.319	**0.012**	0.985	**0.001**
	SCL	Mean skin conductance level (micromhos)	11.10(3.00)	11.56(3.46)	11.41(3.49)	11.75(3.60)	11.17(3.04)	0.434	0.183	0.448	0.281	0.781	0.176	0.842	0.275
	SDSCL	Standard deviation of skin conductance level	0.42(0.24)	0.06(0.48)	0.48(0.30)	0.57(0.58)	0.56(0.50)	0.634	0.300	0.502	0.156	0.448	0.611	0.373	0.631
	ΔSCL	Skin conductance level difference (micromhos)	0.00(0.00)	0.46(1.40)	0.31(1.37)	0.64(1.57)	0.07(1.12)	0.433	0.183	0.448	0.281	0.781	0.176	0.842	0.275
Eye Behavior	SDHG	Standard deviation of horizontal gaze (m)	0.47(0.16)	0.40(0.11)	0.39(0.11)	0.34(0.11)	0.45(0.10)	**0.005**	**0.004**	0.053	0.115	0.662	**0.044**	0.495	0.089
	SDVG	Standard deviation of vertical gaze (m)	0.31(0.13)	0.28(0.10)	0.27(0.10)	0.27(0.09)	0.28(0.12)	0.232	0.067	0.094	0.070	0.779	0.727	0.292	0.818
	HG	Mean horizontal gaze (m)	0.03(0.27)	-0.04(0.30)	-0.05(0.31)	-0.09(0.29)	0.01(0.31)	0.081	**0.046**	0.123	0.194	0.541	0.282	0.730	0.086
	VG	Mean vertical gaze (m)	0.58(0.39)	0.53(0.40)	0.57(0.37)	0.56(0.41)	0.52(0.34)	0.521	0.656	0.781	0.316	0.186	0.712	0.195	0.779
	BF	Blink Frequency (Hz)	0.49(0.29)	0.54(0.24)	0.58(0.26)	0.60(0.24)	0.48(0.26)	0.340	0.060	0.064	0.110	0.427	0.595	0.811	**0.041**

Geisser correction was applied for models that violated the assumption of sphericity. Post-hoc pair-wise comparisons were computed for significant effects using a least significant difference (LSD) correction.

3. RESULTS

3.1 Ratings of Driving Workload

In order to investigate the effect of the cognitive workload induced by secondary tasks, the primary driving workloads were subjectively evaluated and confirmed that the workloads across five periods, i.e., baseline, three n-backs, and recovery, were not significantly different ($F(4, 37.924) = 2.468$, $p=.078$). The average driving workloads of baseline, 0-back, 1-back, 2-back and recovery were 2.6, 3.2, 3.0, 2.8 and 2.9, respectively.

3.2 Secondary Task Performance Measures

Error rates on the n-back tasks during the driving only and dual-task conditions appear in Table 1. The overall higher error rates under dual task condition mean that the demands of the primary driving task reduced the cognitive resources available to invest in the n-back. The error rates were increased as the level of cognitive task difficulty increased under both driving only conditions and the dual-task condition. However, the error rates of baseline n-back tasks were not significantly changed, because the error rates were very low across all three levels. This means all participants were highly engaged to perform the n-back tasks. For the dual task condition, the cognitive task difficulty significantly impacted on the secondary task performance.

3.3 Driving Performance Measures

As shown in Table 1, the participants significantly decreased vehicle speed as the level of cognitive task difficulty increased. The mean speed profiles showed a simple correlation with the level of cognitive workload, but the standard deviation of speed was subtle. For the lateral control ability measures, SRR measures were significantly impacted by the difficult level of cognitive workload. However, SRR in the baseline period is relatively high because the geography of baseline area was curvy downhill. Thus, Modified SRR (MSRR) was calculated by replacing the baseline with the recovery value. The MSRR profiles did show a relatively simple correlation with the cognitive level and post hoc comparisons show significant differences between some of these periods (baseline to 1-back and 0-back to 2-back). It means SRR have moderate sensitivity to differentiate the graded levels of cognitive demand and could be one of good effective cognitive measures when a driver baseline is appropriately selected.

3.4 Physiological Measures

To observe the physiological response change under different cognitive demand level, IBI, SDIBI, HR, SDHR, HRV, ΔHR, SCL, ΔSCL, SDSCL were investigated (see Table 1). Among the cardiovascular activity-based measures, IBI, HR and ΔHR were significantly impacted by cognitive task difficulty. They could differentiate most of different cognitive demand levels (baseline to 0-back, 1-back to 2-back, 0-back to recovery) except the difference between 0-back and 1-back. The main effect of cognitive demand also significantly impacted on SDHR but its pair-wise significance was limited. For the electrodermal activity-based measures, all SCL related measures were not significantly impacted by cognitive workload. These results are inconsistent with earlier findings. The reason is unclear at the moment and more careful review of experimental settings such as sensor attachment and sample differences is required.

3.5 Eye Behavior Measures

To observe the eye behavior change under different cognitive demand level, SDHG, SDVG, HG, VG, and BF were examined. Two eye behavior measures including SDHG and BF were significantly impacted by cognitive demand. SDHG could differentiate higher cognitive demand levels (baseline to 2-back, 0-back to 2-back, 1-back to 2-back), but the sensitivity of BF was limited. In this study, the sensitivity of SDHG is slightly different from Reimer's results [5] and this will be discussed in discussion section. The main effect of cognitive demand did not significantly impact on HG and VG in this study.

4. DISCUSSION

N-back error rates from both the non-driving and dual task period were increased in difficulty across the task levels. Coincident with this, several cognitive measures in multiple domains, including HR and ΔHR in physiological domain, SDHG in eye behavior domain, and SPD and MSRR in driving performance domain, showed an unambiguous increase in mean value for each level of heightened demand.

In the physiological measurement domain, patterns of change in heart rate under added cognitive demand was consistent with the earlier findings of Mehler et al. [3] except pair-wise significance between 0-back and 1-back. The difference between Mehler's results and this study could be caused by the environmental factors. As shown in Table 1, the increment in error rates between 0-back and 1-back was very small in both of non-driving and driving conditions, i.e., 0.74% under non-driving condition and 1.30% under dual-task condition. It means the difficult level of 1-back was slightly higher than that of 0-back and overall workload can be easily changed by environmental factors. In this study, the average driving workload during 0-back (workload rating: 3.2) was higher than that of 1-back (workload rating: 3.0). Thus, it can be speculated there was no difference between 0-back and 1-back period, because the combined cognitive workload was almost same due to the environmental factors. Although the driving workload induced by environmental factors was not reported in Mehler's study, the added cognitive demand between 0-back and 1-back seems to be limited to represent low and moderate cognitive demands.

In the eye behavior measurement domain, the results on horizontal eye movement were similar to the findings of Reimer et al. [5], but the patterns in gaze constriction and sensitivity in low and moderate demand were slightly different. Reimer's results showed that horizontal gaze concentration constricted in a relatively linear fashion and bottom out in 2-back. In this study, however, the highest constriction appeared in 2-back. This variation in pattern between the two studies seems to be caused by variability in the samples, i.e., the sample of 108 individuals was equally balanced by gender and across three age groups: 20 to 29 (M=24.6, SD=2.7), 40 to 49 (M=44.5, SD=3.0), and 60 to 69 (M=63.3, SD=3.1) in Reimer's study. On the other hand, the difference in sensitivity between 0-back and 1-back can be caused by the driving workload difference between the 0-back and 1-back periods as mentioned before.

In summary, this study provides general understanding of various measures for detecting the difficult levels of driver's cognitive demand. The results suggested that the patterns of change in HR, SRR, and SDHG with increasing mental workload showed near linear correlation. Among these effective cognitive measures, physiology, especially mean heart rate, showed the most sensitive response and seems to be the best independent indicator of changes in cognitive workload. Other options besides heart rate, SDHG in eye movement and SRR in driving performance measures can be used for detecting the presence of cognitive workload. Especially, SDHG could be considered one of the most useful measures in the eye behavior domain, because the vision-based approach would be capable to detect not only cognitive demand with reasonable sensitivity but also visual distraction with high accuracy. Nevertheless, the steering wheel reversal rate (SRR) is highly recommended to use for discriminate moderate level of cognitive demand, because SRR could be collected through the easiest and less expensive way. The steering reversal rate in the driving performance domain can be a commonly used measure by combining with the other domains' measures. These measures can be used for evaluating cognitive workload associated with voice interaction system, represents a potential distraction from the driving task.

5. ACKNOWLEDGMENTS

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Sources of Cognitive Load in a Simulated Law Enforcement Patrol Task

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ABSTRACT
Unlike in civilian driving, law enforcement officers are required to multitask for effective job performance. In addition to the traditional radio and radar equipment, integrated mobile data terminals are finding their way into patrol vehicles, adding additional features, flexibility, and potentially cognitive load to the already demanding patrol task. Because of the working memory and attentional demands of patrol, it is imperative that the impact of in-vehicle technology interfaces be considered. For the current project, sworn law enforcement officers completed a simulated patrol task that required them to interact with a semi-automated dispatch system and an in-vehicle data terminal that either 1) visually presented dispatch information (working memory support) or 2) presented only a map of the environment.

Categories and Subject Descriptors
H.1.2. [**User/Machine Systems**]: Human factors, human information processing, J.4. [**Social and Behavioral Sciences**]: Psychology.

General Terms
Human Factors, Design, Experimentation.

Keywords
Law Enforcement, Driving Simulation, Driver Multitasking.

1. INTRODUCTION
When it comes to discussions of driver multitasking and performance, the primary focus is on the impact of in-vehicle and mobile technologies for the civilian driver (e.g., [1]). In most civilian situations, interactions with in-vehicle systems can be viewed as distracting the driver from the primary task of controlling the vehicle. As examples, a cellular phone conversation may reduce a driver's reaction time [2], or a navigation display may capture the driver's attention (e.g., [3]). However, there are a number of professional driving domains that require vehicle operators to interact with technology for effective job performance. Many occupations require drivers to regularly navigate potentially unfamiliar areas, and to interact with technology while doing so, such as a logistics management system on a fleet of commercial vehicles or a mobile data terminal in a law enforcement patrol vehicle. The most visible and potentially most cognitively demanding of these domains is law enforcement patrol.

Law enforcement patrol requires officers to observe and monitor the activities of vehicles and individuals in the external environment while simultaneously maintaining control of the patrol vehicle. The observational skills of law enforcement officers are critical for their reports as well as for later legal proceedings. Although the traditional patrol vehicle may be imagined as including only a radio for communication to dispatch and a radar speed detection system, the current patrol vehicle includes far more (e.g., [4]). Video recorders, license plate readers, and computer-assisted dispatch interfaces restrict available space and range of motion and add visual complexity within the vehicle cockpit. These restrictions may result in increased cognitive workload for officers in the field. However, if designed well and integrated with the vehicle to minimize complexity and space demands, a mobile data terminal may also improve officer performance by leaving more attentional and working memory resources available for processing the current situation (i.e., situation awareness, [5]) rather than merely maintaining an acceptable level of performance.

2. METHOD
As part of a project funded by the National Institute of Justice, we brought officers from three regional municipal police departments to the Center for Advanced Vehicular Systems (CAVS) Driving Simulation Laboratory to perform a simulated patrol task.

2.1 Participants
Fourteen sworn law enforcement officers from three municipal departments volunteered for 2.5 hours in return for $50 compensation. Depending on the distance traveled from the municipal department and CAVS, officers may have also received an additional travel allowance.

2.2 Materials and Apparatus

The CAVS Driving Simulation Laboratory includes a full-size vehicle cab mounted on a six degree-of-freedom motion base platform, designed and installed by Realtime Technologies, Inc. (RTI, Royal Oak, MI). Three large screens are located ahead of the vehicle to provide approximately 180-degrees of visual angle. An additional screen is located behind the cab and visible in the internal rear-view mirror. On-board LCD monitors act as side mirrors. The vehicle is controlled via the original steering wheel, accelerator and brake pedals, and automatic gear shift lever. The dynamics model is customizable, but for the current project, a standard full-size sedan model was used.

To simulate the in-vehicle mobile data terminal, an ultraportable notebook computer was mounted just above and to the right of the gear shift. In all drives, the computer presented a static map of the driving environment and a text box for the presentation of dynamic dispatch messages (see the following section).

2.3 Procedure

Officers completed five patrols (see Table 1) in a generic city driving environment, in one of four dispatch conditions: naturalistic language with a dynamic display, naturalistic language with a static display (map only), or coded language (ten-codes, e.g., 10-4 for “acknowledged”) with a dynamic display or a static display. The fifth driving condition was a ‘Baseline’ condition without dispatch information in which officers only responded to environmental events. The order of conditions was counterbalanced for all participants. Each drive took between fourteen and twenty minutes to complete.

Table 1. Drive conditions for simulated patrol task

Drive	Communication Format	Display Type
1	Naturalistic	Dynamic
2	Naturalistic	Static
3	Coded	Dynamic
4	Coded	Static
5	Baseline	Static

During the four dispatch conditions, participants monitored and responded to calls for service via an automated dispatch system. Participants were assigned a call sign. The simulated dispatcher assigned calls to the participant and three other simulated officers. The participants were expected to monitor the status of other (simulated) officers, since in actual patrol operations they may be called on as backup.

During all five drives, eye movements and in-vehicle MDT interactions were recorded via video. The in-vehicle MDT always presented the environment map; in the dynamic display conditions, additional information including the current call for service and location address was presented in either coded or naturalistic language. This information was presented in a simple sentence format, nearly identical to the auditory message provided by the dispatch recording.

When participants either arrived on scene in response to a call for service via dispatch or witnessed an event that required a response from them, they were to put the vehicle into ‘Park’ and then press the Space bar on the mobile data terminal (MDT). At this point, the view of the environment was obscured by presenting a black screen, and participants answered three questions presented in a four-alternative forced-choice format about the current event and related radio chatter for other ‘officers’ on patrol. These questions examined participant’s memory for the characteristics each event, such as how many individuals or vehicles were involved, where the call for service was located, and whether a specific officer was currently responding to a separate event or ‘in-service’ (i.e., patrolling the environment).

2.4 Data Analysis

Data was collected from three primary sources: the driving simulator, the eye tracker, and the video recording system. All sources were integrated using SimObserver [6] and annotated using Data Distillery [7]. Eye movement recording was overlaid onto the video, and both the video and the eye movements were independently coded by at least two experimenters prior to compilation and analysis. Driver performance data (e.g., control inputs, lane position) were recorded by the simulation system and were available in a spreadsheet format in Data Distillery.

Two approaches to coding the data were taken by experimenters. Initially, eye glances to the MDT and the external environment (e.g., other vehicles, pedestrians, street signs, etc.) were coded. This approach was used to code data for six of the fourteen participants, with inter-rater agreement ranging from 74% to 95%. Given the substantial time requirements of this coding approach, we shifted focus to only coding glances to the MDT. When coding only the MDT, inter-rater agreement ranged from 95% to more than 99%. Regardless of which approach was used for a particular participant, only the MDT glance data were considered for the following analyses.

3. RESULTS

Figure 1 shows the percentage of time while driving spent attending to the in-vehicle MDT (including the environment map). In all but the Baseline condition, participants spent roughly 7% of the time attending to the MDT display while the vehicle was in motion (i.e., while driving). A repeated measures ANOVA was conducted, and found a significant difference across conditions, $F(4, 44) = 5.56$, $p < .01$.

Upon further inspection, we found that the only statistically different condition is the Baseline condition, in which there was no radio dispatch communication and therefore no calls for service that required navigation to a given location. As anticipated, there were no significant differences among the drive conditions once the Baseline condition was excluded, $F(3, 36) = 2.20$, $p = .10$.

Another potentially interesting statistic is what percentage of time spent looking at the in-vehicle MDT occurs when the vehicle is in motion compared to when it is stopped (e.g., at a traffic light or stop sign, or along the side of the road). Figure 2 gives the percentage of time spent attending to the MDT while the vehicle was in motion as a ratio to total time spent on the MDT across the drive. This is distinguished from the data in Figure 1, which is the ratio of time spent on the MDT while in motion over total drive time (i.e., not only time spent on MDT).

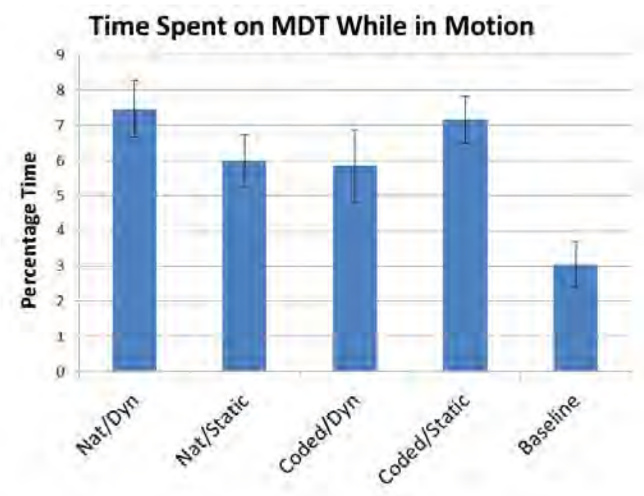

Figure 1. Percentage of time spent on MDT while vehicle was in motion, by condition. Error bars indicate standard error of the mean.

With the exception of the Baseline condition, participants were driving for between 25% and 30% of the time spent attending to the MDT. This is likely an underestimation of the actual time spent looking at the MDT while driving since this number also includes the time participants were completing the situation awareness assessment (during which the driving environment was replaced with black screens and the vehicle was "parked").

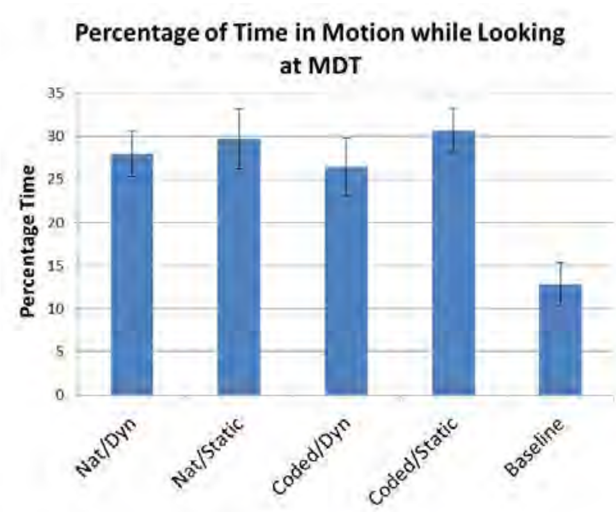

Figure 2. Time spent on MDT while vehicle in motion as a percentage of total time on MDT, by condition. Error bars indicate standard error of the mean.

As was the case with the overall percentages of time spent attending to MDT while driving, the only condition that differed significantly was the Baseline condition (with Baseline, $F(4, 44) = 5.25$, $p < .01$, and excluding Baseline, $F(3, 36) = 0.31$, $p = .82$).

More broadly, results from the situation awareness measures have been presented previously [8]; these results indicated that the coded language conditions were most sensitive to the presence of the dynamic display conditions compared to the naturalistic language conditions in which there were no significant differences. Figure 3 shows the error rates for the situation awareness assessment by condition.

4. IMPLICATIONS

The previous situation awareness results [8] indicated that the coded language conditions were most sensitive to the presence of the dynamic display conditions compared to the naturalistic language conditions in which there were no significant differences. Because naturalistic language is processed automatically, participants may have found retaining this information in memory less challenging than in the coded language conditions, leaving more attentional resources available for processing the current situation. In contrast, the use of coded language may be more concise for communicating across the radio, but it also requires more active interpretation by the individual receiving it; in those situations, the additional memory support provided by the displayed dispatch information may have allowed participants to process the current situation more effectively, resulting in improved performance.

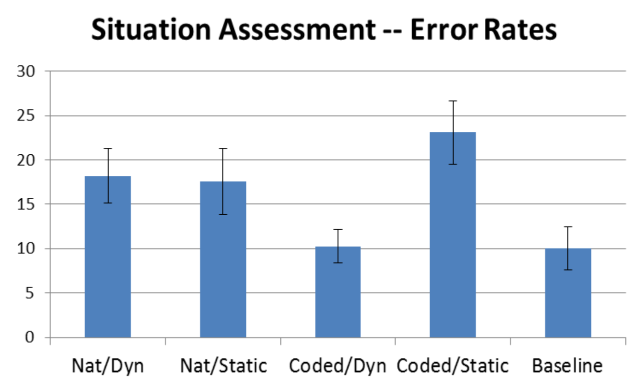

Figure 3. Error rates for situation awareness assessment questions, by condition.

Although the only statistically significant difference in viewing of the MDT is that participants spent less time looking at the MDT in the Baseline condition (given that there was no requirement or necessity to do so) compared to the conditions with radio dispatch, the trend toward an interaction across communication and display type is potentially interesting. Time spent looking at the display increased when additional information was presented for the naturalistic conditions, but decreased (non-significantly) in the coded language conditions. Participants also spent slightly (i.e., not significantly) more time attending to the MDT when the vehicle was in operation in the conditions with no dispatch information displayed.

Considering the MDT results (Figure 2) with the situation awareness results (Figure 3), it appears that participants may have been able to offload some of the cognitive demands of maintaining information presented in coded language to the MDT without requiring substantial attention to the MDT. The additional display information did not seem to have any significant impact on the naturalistic conditions, which are roughly equivalent.

Although the dynamic display condition does trend higher in total time (see Figure 1), the proportion of time spent on the MDT while in motion is comparable across the two conditions (Figure 2).

Considering the task of law enforcement officers on patrol, the observed 25-to-30% of attention to the MDT occurring while the vehicle is in motion is potentially problematic. Patrol officers tend to spend a substantial portion of their shift driving, and much of the information that they must attend to will be presented on the in-vehicle display. Although the information presented can alleviate cognitive demands, the fact that the officers looked away from the forward roadway for a substantial amount of time could create a dangerous driving situation [9]. Follow-up analyses will include the duration of individual glances in order to compare the current data to the current in-vehicle interface standards of avoiding glances longer than 2 seconds [10].

The current project is limited by the small sample size, which inevitably is reflected in the lack of clearly significant results. This is a product of multiple factors: a specialized population and a challenging simulation that increases the potential for simulator adaptation syndrome (simulator sickness). Given that the original intent of the project was to simulate the experience of law enforcement officers on patrol, these limitations were necessary. Future work in this area should leverage current law enforcement driver training programs that use simulators to both improve statistical power and simplify scenario development. In addition, a second (or perhaps even primary) eye tracking and/or video recording system should be located near the MDT to more directly observe attentional shifts to the display and thus away from the forward roadway.

5. ACKNOWLEDGEMENTS

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The ConTRe (Continuous Tracking and Reaction) Task: A Flexible Approach for Assessing Driver Cognitive Workload with High Sensitivity

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ABSTRACT

The importance of understanding cognitive load in driving scenarios cannot be stressed enough. With a better management of cognitive resources, many accidents could be avoided, hence it is one of the most critical variables that user experiments attempt to investigate when new in-car systems are introduced. Since there is currently no way to measure it directly, it is often estimated via its impact on primary task performance.

Driver assistance systems have traditionally sported rather simple and uni-modal HMIs, but the recent increase in variety of in-vehicle information systems (IVIS) suggests that a more distinguished look at measurement tasks may be needed. Our research indicates that the few established tasks may not be suitable for estimating distraction in all cases, which consequently makes them an unreliable predictor for cognitive load. For the specific conditions we require in our investigation (e.g. continuity, controllable difficulty etc.), we propose the *ConTRe* (Continuous Tracking and Reaction) Task, which complements the de-facto standard lane change test in order to provide more insight in these cases.

Categories and Subject Descriptors

I.6.m. [**SIMULATION AND MODELING**]: Miscellaneous

General Terms

Measurement, Documentation, Performance, Design, Reliability, Experimentation, Human Factors.

Keywords

cognitive load, workload, driver distraction, driving task, driving simulator

1. INTRODUCTION

During the last decades numerous new in-vehicle information systems (IVIS) have been introduced into modern cars (e.g. navigation systems, media players, travel information, vehicle communication systems, driver convenience services). As most of them can be controlled while driving, it is important to consider possible effects of system usage on driving performance. Prior to bringing these systems onto the road for customers, their influence on driving performance is measured in test-track and on-road studies. Moreover, even before using real cars, because of safety and liability issues new systems need to be tested in driving simulators to investigate effects on cognitive workload and potentially driving performance. A further advantage of simulator studies is the controllability of tracks, situations and exact conditions leading to fewer confound and therefore more efficient evaluation e.g. if you want to find out about differences between systems or interindividual differences. While the importance of simulator studies in general is undisputed, it is an entirely different question how the task should ideally look like for a given system evaluation (e.g. lane change task, vehicle platooning task, wayfinding according to navigation instructions) and which out of numerous metrics (e.g. brake reaction times, lane exceedences, steering angles, glance durations) should be chosen. In the following, we present some common driver distraction measurement approaches and driving simulation solutions, followed by a short summary of our open source driving simulator *OpenDS*. Next, we introduce the *Continuous Tracking and Reaction (ConTRe)* Task and discuss its characteristic advantages for driving performance assessment and inferences with regard to cognitive load. Finally, we will provide first results achieved with the *ConTRe* Task in a recent user study.

2. BACKGROUND

So far, there exist common performance metrics used in driving simulations, as for example vehicle following, lane keeping, or event detection [8]. This variety of metrics can be recorded with the help of rather expensive and complex commercial driving simulators (e.g. [3]). Alternatively, there are some low-cost approaches available for measuring driver distraction. For example, [7] have used the racing simulator *rFactor*, which was originally developed for the entertainment market with a focus on physically believable racing experience. *rFactor* provides the feature of developing and using additional plug-ins. However, the developer is very restricted when creating them: It might be possible to create new racing tracks, but it is not possible to create a complex street system, which would be needed to construct urban areas. Other cars controlled by the computer can be inserted and their general driving style can be modified, but the driving path of these cars or the time they start moving cannot be controlled. Another low-cost driving simulation solution is the *Configurable Automotive Research Simulator (CARS)*, which has been developed and made available as an open-source project [2]. This latter aspect leads to a more flexible solution for researchers, as the source code of *CARS* can be accessed and modified, if necessary. However, *CARS* has two major limitations, which are rooted in its architecture. On the one hand, the map editor, which is contained in the *CARS* software package, severely restricts the size of the maps that can be created. Another disadvantage is the fact that the *CARS* map editor employs a proprietary map format and does not incorporate a standard compliant data format for neither import nor export. The driving simulator itself is also constrained to this map format.

In addition to the aforementioned driving simulation solutions, there exist surrogate driver distraction measurement techniques, like the ISO-standardized lane change test (LCT) [4, 6], which was especially developed for low-cost driving simulators. The LCT is a valuable approach for evaluating the impact of a secondary task on driving performance (i.e. lane keeping, detection of instructional signs and lane changing). Advantages from classic reaction time measurement approaches are integrated into a cost-efficient simulation tool, which provides reliable and valid evaluation results [5]. This has lead to a widespread usage of this task within the research community. However, the LCT has some major drawbacks, which might make it unusable for specific research questions and encourage the design of a novel task. First of all, in the LCT it is not possible to compare interface tasks interrelated with the actual driving situation (e.g. it cannot be used to test new interfaces for navigation systems), as the tracks, the signs and the task are fixed and the 3D model cannot easily be extended. But even if that is not an issue, a researcher might still want to change parameters like task difficulty in order to investigate influences in easy driving conditions opposed to more challenging ones. Another requirement might be a more fine-grained evaluation of driver distraction in terms of temporal resolution. For the task in LCT, drivers only need to change the lanes once in a while by conducting a rather abrupt maneuver combined with simple lane keeping on a straight road in between. But real driving mostly demands rather a continuous adjustment of steering angle and speed without knowing when the next incident will occur. This would require a task which bears more resemblance in interaction to e.g. a car following task. Furthermore, the performance metric is based on a generated, normative model as the ideal line used in the LCT rather than an absolute ground truth of perfect behavior.

The *ConTRe* Task introduced in this paper was created to overcome some of the limitations of the aforementioned approaches. As such, it should be sufficiently controlled to eliminate major subject failures, like going in circles or colliding with objects by mistake, which would interfere with the automatic performance evaluation. Track length and duration should moreover be adjustable according to secondary task demands. Another intended advantage of the *ConTRe*

Figure 1: A screenshot of the *ConTRe*. The driver controls the movements of the blue cylinder while the yellow cylinder moves autonomously.

Task over the LCT and also many other standard tasks is the possibility to explicitly address mental demand via a central or peripheral detection task. Effects of cognitive load should be revealed above all by the achieved reaction times. This additional discrete task should be accomplished in addition to the continuous adjustment of steering wheel angles for lateral control, and therefore was implemented as longitudinal control (gas and brake). Each of these two tasks or their combination will provide in general a very sensitive and controlled tool that can, for example, be used for system comparison in early design lifecycle evaluations.

Summing up, we present a new extremely flexible and sensitive task for measuring driver distraction. To facilitate optimal customizability, the task was implemented as part of our modular open-source driving simulation *OpenDS* and can be extended by any programmer of the community. The development of the software is fostered by the EU-project *GetHomeSafe*[1]. The simulation provides an accurate physical environment with realistic forces, lighting, and road conditions. Objects and events can be placed, and traffic can be simulated. A driving task editor can be used to design a task suited for a given experiment, while the simulator runtime provides extensive logging of the subject's driving, and evaluation tools allow both computation and visualization of various metrics, such as deviation from a reference drive.

3. CONTRE TASK DESCRIPTION

The driver's primary task in the simulator is comprised of actions required for normal driving: operating the brake and acceleration pedals, as well as turning the steering wheel. System feedback, however, differs from normal driving. In the *ConTRe* task, the car moves autonomously with a constant speed through a predefined route on a unidirectional straight road consisting of two lanes. Neither operating the acceleration or brake pedal, nor changing the direction of the steering wheel does have an effect on speed or direction of the vehicle. Accordingly, motion rather feels like a video clip. Steering, braking and using the gas pedal do not actually control the car, but instead manipulate a moving cylinder which is rendered in front of the car. On the road ahead, the driver perceives two such cylinders, which continuously move at a constant longitudinal distance (20 meters) in front of the car. The two cylinders differ only in color: one is blue and the other one is yellow. The latter is called the reference cylinder, as it moves autonomously ac-

[1]http://www.gethomesafe-fp7.eu

cording to an algorithm. The movement direction and the movement speed of the reference cylinder are neither controlled nor predictable by the user, except that the cylinder never exceeds the roadsides. In contrast, the driver controls the lateral position of the blue cylinder with the help of the steering wheel, trying to keep it overlapping with the reference cylinder as well as possible. As the user turns the steering wheel, the controllable cylinder moves to the left or to the right, depending on the direction of the steering wheel and its angular velocity (i.e. the steering wheel controls the cylinder's lateral acceleration). Effectively, this corresponds to a task where the user has to follow a curvy road or the exact lateral position of a lead vehicle, although it is more strictly controlled and thus with less user-dependent variability. Furthermore, there is a traffic light placed on top of the reference cylinder containing two lights: The lower one can be lighted green, whereas the top light shines red when it is switched on. Either none or only one of these lights appears at a time. The red light requires an immediate brake reaction with the brake pedal, whereas green indicates that an immediate acceleration with the gas pedal is expected. As soon as the driver reacts correctly, the light is turned off (see Figure 1).

This task set-up can be adjusted to meet the requirements of a particular experiment by means of modifying certain control variables. This includes the displacement behavior of the reference cylinder and the frequency of the brake and acceleration situations, which can be set before beginning the driving task. The displacement behavior in turn is affected by the displacement velocity, acceleration, and rate of changes. By manipulating these factors, the difficulty level of the driving task can be changed. The driving task can be very challenging when the reference cylinder moves with high speed and the driver has to brake or accelerate frequently due to the condition of the traffic light.

Using this simulator setup, different measurements can be obtained. One value of interest is the distance metric between the reference cylinder and the controllable cylinder. This distance measurement is internally calculated in meters. However, as the width of the street is a fixed value (8 meters), it is transformed into a value relative to the width of the street, where 100% deviation corresponds to the width of a full lane in this two-lane scenario. This way, the resolution of the simulator display will not affect the measurements, as they are calculated relative to the street width. Other relevant values are the reaction times of operating the acceleration or brake pedal, and number of errors (wrong usages of these two pedals) or omissions.

4. EXPERIMENTAL DATA

Since the proposed task has not been published before, no large-scale experience could be obtained with it yet. Instead, our goal with this paper is to give an impression of results that can be achieved with this task and to underpin the internal validity of the method, i.e. to give a proof of concept. For this reason, we present some results of a driver distraction experiment (to be published separately) that was conducted in our lab and that was part of the original motivation for suggesting this task. The goal of the study was to investigate user and context adaptation of interaction concepts for IVIS with respect to driver distraction, secondary

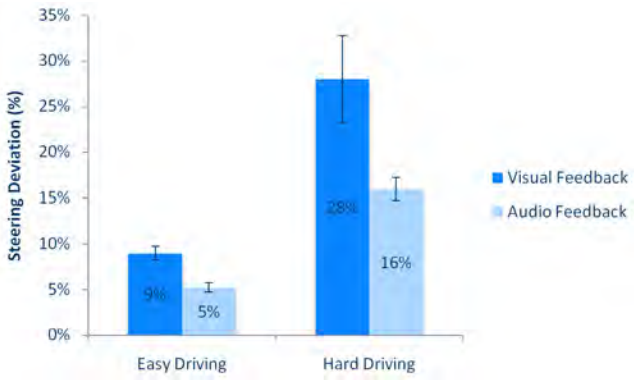

Figure 2: Average steering deviation (in percent, y-axis) and standard error in two driving scenarios (easy and hard, x-axis) and using two output modalities (visual and audio) recorded from 24 participants performing the *ConTRe* Task.

task performance, and user acceptance. We assume that an intelligent, adaptive IVIS would be able to provide better safety and value by taking the current context into account [1]. This lead to the more concrete hypothesis that different contexts (e.g. driving difficulty: easy vs. hard) would moderate driving performance for two different feedback modalities (visual vs. audio feedback). One varying driving context is the traffic situation, which – for simplicity – was divided into the two categories *easy* and *hard* in the experiment. Using the *ConTRe* Task's ability to control tracking bar movement speed, the two categories were mapped to two difficulties, reflecting the need for increased correction movements during fast driving or in heavy traffic. The IVIS (secondary task) was a basic POI selection app, and the interaction concepts available to the system were visual and audio feedback. While doing the *ConTRe* Task, participants were asked to find POIs of a certain type on a map shown on an auxiliary screen, which could only be done by selecting POIs (using a touchscreen) and then reading or listening to the details provided by the system. The interaction in this task is not connected to the driving context, hence this precondition for using *ConTRe* is satisfied.

Figure 2 shows the average steering deviation recorded from the subjects in all four combinations. Several reasonable hypotheses are plausibly confirmed by these figures: First, the easy driving condition always causes lower deviation than the hard driving condition ($F(1, 23) = 49.2; p < .001$). This implies high content validity for measuring the driving difficulty levels. Second, for the individual driving difficulty levels the visual modality causes a higher distraction than the (eyes-free) audio modality showing quite a high sensitivity of the method ($F(1, 23) = 12.51; p < .01$). Third, the difference between modalities is stronger in the hard driving condition ($t(23) = 2.78; p < .05$), leading to the conclusion that sensitivity is even high enough to determine quantitative differences between conditions. In addition to this metric, using *ConTRe* as the primary task, further observations were made: The number of completed tasks within a track of constant length is also lower in the hard driving condition, although this effect is not cross-modal ($t(23) = 3.33; p < .01$ for visual and $t(23) = 3.11; p < .01$ for audio). On the other hand, the number of completed tasks is always higher in the visual condition ($F(1, 23) = 25.95; p < .001$). For most of the other experiments conducted as part of the study, the hypotheses could likewise be confirmed. Apart from their implications on the experiment goal, the means and standard errors reflected in these figures suggest that the proposed task does indeed provide a solid basis for experimental investigation of fine-grained effects on driver distraction.

5. CONCLUSION

The *ConTRe* Task introduced in this paper extends the assortment of solutions available for measuring driver distraction in simulator environments. It was created to compensate certain potentially weak points of other driving tasks. We expect that user experiments with similar characteristics, as the study of adaptive IVIS described in the previous section, will benefit from the continuity and clean design of the task. A more sensitive task reveals more subtle effects, as significance tests benefit from less experimental data noise and from having a reliable ground truth available. This will again enhance the investigation of cognitive workload, as a more fine-grained evaluation of driving performance will better reveal even a slight decrease in performance induced by higher - or too low - cognitive load. Furthermore, flexibility in driving task difficulty is retained through various configurable parameters. Varying or adjusting current driving task difficulty during a track might be a valuable extension for cognitive workload assessment in the future. While the user study has served successfully as a first application of our new method, additional experience as well as a more formal comparison of different methods are part of future work that is needed to establish the *ConTRe* Task as a permanent constant in the driving task ecosystem.

In this paper, we have presented a high-level description of the implementation. Since the task is written as a driving task "plug-in" for the new extensible open source driving simulation platform *OpenDS*, it will be made freely available in conjunction with the latter within a narrow time frame. Likewise, we will be further enriching the framework with different driving tasks, including some that are more linked to specific and realistic driving conditions, to reach an even broader coverage of test scenarios for driver distraction related to modern in-car systems.

6. FUTURE WORK

Estimating cognitive load will remain a challenge for the next years. Driving tasks such as *ConTRe* bring us one step closer to our goal of reliable and expressive metrics, if we assume a correlation between distraction and load. In a more general sense, we believe that we will not discover a way to measure workload directly in the near future, if at all. Instead, the truth can be approximated by approaching the problem from two perspectives: an observating and a generative strategy, which we both recommend to be equally pursued by future research.

The former category, to which all driving tasks belong, attempts to estimate the current workload by observing and evaluating the subject's state and reactions. An advantage of this method is that it can be applied without knowledge of the subject's context and other tasks. The second category, the generative methods, attempt to analyze the factors influencing the subject's cognitive load, such as context factors (e.g. density of traffic, driving time etc.) or secondary tasks (complexity of the HMI presentation or interactions performed by the driver). This requires a more extensive amount of knowledge, but has the advantage of being able to also predict changes to workload incurred by a certain system behavior. These aspects are part of a separate line of future work that we are looking into and should also take a prominent place on the community's roadmap.

A third line of work should deal with the relation of the production and measurement side of cognitive load, which are both joined by a cognitive load model. Being able to extend the *ConTRe* Task towards a dynamically and individually adaptable scenario will highly support this line of research. Once we have found and empirically confirmed such a relationship between cognitive workload generation and measurement, this can be seen as strong evidence that the underlying model and formulas are close to the actual processes, hence we consider this a long-term goal of cognitive load modeling.

7. ACKNOWLEDGMENTS

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Data Synchronization for Cognitive Load Estimation in Driving Simulator-based Experiments

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ABSTRACT
Analyzing the effects of driver distraction and inattention on cognitive load has become a very important issue given the substantial increase in the number of electronic devices which are finding their way into vehicles. Typically separate equipment is used for collecting different variables sensitive to cognitive load changes. In order to be able to draw reliable conclusions it is important to possess dependable ways of synchronizing data collections between different equipment. This paper offers one low-cost solution which enables synchronizing three types of devices often used in driving research: driving simulator, eye-tracker and physiological monitor.

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

General Terms
Measurement, Experimentation.

Keywords
Data synchronization, cognitive load, eye tracking, driving simulator, physiological measurements.

1. INTRODUCTION
In recent years we have seen a major increase in research concerned with driver distraction and the influence of various in-vehicle devices on driving performance and cognitive load. This development is not surprising for two reasons. First, the amount of time people spend in their vehicles has been steadily increasing, with 86.1% of American citizens commuting in a car, truck or van in 2009 and spending on average 25.1 minutes driving to work (one way) daily [1]. And second, with the proliferation of computers and the expansion of communication networks, new types of electronic devices are becoming available and being introduced in vehicles at a rate never seen before. Those new devices typically make the driving experience more interesting and enjoyable. However, this comes at a price of an increased number of accidents caused by driver distraction and inattention [2]. Therefore it is necessary to have reliable tools which can detect the potential for distraction that an in-vehicle device has before it is introduced in vehicles.

There are many measures that can be sensitive to changes in cognitive load and they can be divided into three general groups: driving performance (such as steering wheel angle and lane position), physiological (such as skin conductance and visual attention) and subjective measures (such as NASA-TLX). However, many studies have shown that none of these measures is a panacea, thus requiring researchers to often collect more than one measure using different equipment. The fact that different equipment has to be used leads directly to the main problem addressed in this paper: a reliable solution for data synchronization between different data collections is necessary.

2. BACKGROUND
Given the variety of equipment used in driving research it is practically impossible to devise a universal data synchronization solution. Some solutions in that direction do exist, however, at least in the case of equipment which is based on personal computers (PCs).

One example application is called NTP FastTrack [3]. The purpose of this application is to synchronize computer clocks over a data network. It is based on the Network Time Protocol (NTP) [4], where one computer acts as the reference (server) with which other computers (clients) on the network should synchronize. The synchronization is performed by applying small changes to the local clocks of the client computers in order to reduce the difference with respect to the reference clock. The accuracy of this procedure depends on the propagation delay (i.e. load) on the network and can range from 100 microseconds up to several tens of milliseconds. Even though the accuracy is typically high, our experience indicates two problems with this approach. First, it can take a significant amount of time for the synchronization to stabilize (on the order of minutes to hours), which can be impractical if any of the computers need to be restarted or turned off during an experimental session. And second, the equipment which cannot be networked, such as some physiological monitors in our lab, cannot use this protocol.

Recently some commercial solutions for data synchronization have been introduced as well, such as the Tobii StimTracker [5]. The purpose of this device is to enable synchronizing eye-tracking data coming from a Tobii TX300 eye-tracker with several commercially available physiological monitors. It also allows interfacing with a parallel port, thus enabling synchronization with other PC-based equipment. However, this solution has somewhat limited usability, because it was developed for one particular device. Nevertheless, this indicates that the original equipment manufacturers are starting to acknowledge the importance of data synchronization between different equipment.

3. PROPOSED SOLUTION
The main idea behind our solution is in sending the synchronization messages to all the equipment which is used in an experimental trial. Our driving research studies typically involve the following equipment: driving simulator (by DriveSafety), eye-tracker (by SeeingMachines) and physiological monitor (by

Thought Technology). Even though our solution was devised for the equipment made by the above manufacturers, many elements of the proposed approach can be generalized to other equipment as will be indicated in the following sections.

3.1 Hardware Side

Figure 1 shows the block diagram which outlines all the equipment as well as the communication paths.

The first element in the system is the synchronization source PC. It represents the origin of all synchronization messages which are simultaneously sent to other equipment in the system when initiated by an experimenter. In our case this computer runs under Microsoft Windows XP, however, other operating systems that support TCP/IP and serial (RS-232) communication can be used as well.

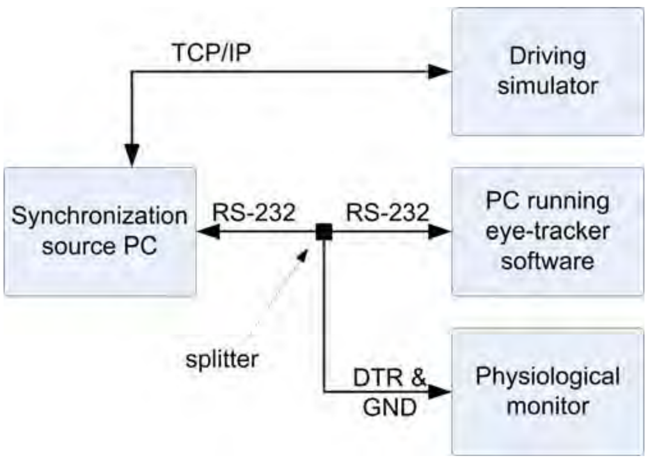

Figure 1. Block diagram of the system.

The following communication paths were established between the synchronization source PC and different equipment:

1. TCP/IP communication with our driving simulator, which is only supported by its scenario scripting system. The local network used for communication supports speeds of up to 100Mb/s. Note that this approach can be extended to PC-based driving simulators as well, which are also commonly used among researchers. Depending on their capabilities either TCP/IP or serial communication could be used.

2. Serial communication with the PC that is running the eye-tracker software. We initialized the following characteristics of the serial communication: 8 data bits, no parity, 1 stop bit, 9600 baud and software flow control set to on.

3. Modified serial communication with the physiological monitor. Our physiological monitor is a standalone A/D converter which can sample multiple physiological signals simultaneously. In that respect it is not able to communicate with other equipment used in experiments. However, it can sample raw electrical signals supplied to any of its inputs. Therefore, we created a splitter (the black square in Figure 1) which isolates two signals from the RS-232 port: Data Transmit Ready (DTR) and ground (GND). These signals are then connected to the physiological monitor through an opto-insulator, that is an electrically insulated switch, and a custom adapter. Whenever the DTR signal is changed to a high voltage level, the switch closes, which then results in a voltage change at the physiological monitor's input. Finally, this voltage change is sampled by the A/D converter. The custom adapter was designed in order to be able to connect the switch to our physiological monitor. In general, this adapter would have to be adjusted based on the particular brand of the monitor. However, the same general approach can be applied.

3.2 Software Side

As we saw in the previous section all three pieces of equipment use different communication alternatives. Therefore, different synchronization messages have to be sent by the synchronization source PC. Although the messages can be sent at any point during the experiment, we propose sending them at the beginning of the experiment. This way the instants in time when the individual synchronization messages are received by each device can be treated as the origins (zero points) on each device's time scale. We designed a custom application (implemented in C++) running on the synchronization source PC, which is capable of sending the following messages:

1. The word "*SYNC*" to the driving simulator over a specified TCP/IP port. The simulator's scripting system periodically polls the selected port at the frequency of 60 Hz. If the word "*SYNC*" is detected, the receipt of the synchronization signal is acknowledged in the driving simulator's database.

2. The symbol "*s*" to the eye-tracker's PC over the RS-232 port. Our eye-tracker's software is unable to check the contents of the serial port. It is for this reason that we created a custom application (again in C++) whose main purpose is to keep checking the contents of the serial port. In order to ensure that the received synchronization signal will be detected in the shortest possible period of time, we ensured that the checking of the serial port is performed in a separate thread by a blocking read call. This means that the application essentially switches to a "listening" state until "*s*" is received. Once this happens, the application immediately reads the local time on the computer and writes it to a log file. This information can then be used to indicate the location of the origin in the eye-tracker's data collection, which is updated at up to 60 Hz and each entry is assigned a local time stamp.

3. The DTR line on the source PC's serial port is toggled from low to high voltage level for a period of 0.5 seconds. During that time the electrically insulated switch is closed, which results in a voltage change on the physiological monitor's input. After 0.5 seconds elapses, the DTR line is toggled back to a low voltage level, which opens the switch. Our physiological monitor samples the changes in voltage levels at the frequency of 256 Hz.

3.3 Testing the Proposed Solution

The precision of the whole system is determined by its slowest component. In our case the slowest components are the driving simulator and the eye-tracker which provide data at the frequency of 60 Hz. Therefore, the synchronization messages should arrive at their destinations within the data sampling period of 1/60 = 16.67 msec.

Let us assume that we want our final data collection to contain observations sampled from all equipment N times per second (this can be accomplished either by setting the sampling rate on each device to be equal to N, or by down-sampling from a higher sampling rate). In this case the maximum transportation delay for our synchronization signal should not exceed $1/N$ seconds. This can be tested by measuring the round-trip delay which takes the synchronization signal to travel from the source PC to the desired destination and back. Based on this information we can then obtain a one-way transportation delay by dividing the round-trip delay by 2.

We performed the above test by periodically (approximately every 2 seconds) sending each of the three synchronization messages 2000 times. The following results have been obtained for the one-way delay:

1. Towards the driving simulator: maximum delay 7.5 msec, minimum delay 0 msec, average delay 6.33 msec, standard deviation 2.73 msec.
2. Towards the eye-tracker's PC: maximum delay 8 msec, minimum delay 0 msec, average delay 7.98 msec, standard deviation 0.198 msec.

Since the physiological monitor is not capable of sending the synchronization signals, we were unable to directly measure the one-way delay. However, we have three reasons to believe that the delay is shorter than the ones observed towards the driving simulator and the eye-tracker's PC. First, by logging the local time we found that the three synchronization messages were always sent at the same instant. This means that no delays (at least on the order of milliseconds) have been introduced between sending different messages. Second, the message towards the physiological monitor is not a data packet, but rather a simple voltage change on the DTR line. Since we selected a baud rate of 9600, the maximum time for this voltage change to occur should be about 1/9600 = 0.104 msec. And third, the physiological monitor's sampling rate is 256 Hz, which means that it can detect a voltage change as fast as 1/256 = 3.9 msec. Therefore, we can assert that the synchronization with the physiological monitor is faster than with the driving simulator and eye-tracker.

4. CONCLUSIONS

Based on these results we can conclude that our proposed low-cost data synchronization solution provides very good performance. For all three types of equipment that we used in our experiments the transport delay of the synchronization signals is much shorter than the data sampling periods of the individual equipment. Specifically, in case of the driving simulator a 7.5 msec delay would allow data sampling rates of up to 133 Hz. For driving performance measures data sampling rates observed in the literature range from 5 to 50 Hz, with 10 Hz being very common [6-8]. In case of the eye-tracker, a delay of 8 msec would allow up to 125 Hz data sampling rates. The rates observed in the literature for eye-tracking data range from 30 to 60 Hz, with 60 Hz being very common [6;7;9;10]. Finally, in case of the physiological monitor, 0.104 msec change in voltage level on the DTR line would allow a maximum data sampling rate of 9.6 kHz (typical data sampling rates in the literature range from 20 to 250 Hz [11-13]).

In the previous section we noted that our driving simulator and eye-tracker provide sampling rates of up to 60 Hz, which results in a 16.67 msec sampling period. Therefore, the overall sampling accuracy of the whole system is determined by these two components. As we had a chance to see, our synchronization procedure provides a maximum delay of 8 msec which is 52% faster than the slowest sampling rate of 16.67 msec.

5. ACKNOWLEDGMENTS

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Comparing Visual and Subjective Measures of Cognitive Workload

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ABSTRACT
As a part of two larger driving simulator experiments focusing on driver distraction, we analyzed the relationship of subjectively reported levels of mental demand (NASA-TLX) and the levels indicated by three visual measures of mental workload (saccadic peak velocity, percent road centre, pupil diameter). The results suggest that the visual metrics resembled the subjective ratings but the direction of the effects were opposite. It is suggested that the proposed visual metrics of mental workload might reflect in this case the influence of the visual demands of the secondary task on an in-car display instead of mental workload. Thus, we suggest that the effects of visual secondary tasks should be carefully considered before making assumptions on mental workload when using visual measures of cognitive workload in multitasking experiments with visual in-car user interfaces.

Categories and Subject Descriptors
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – Evaluation/methodology – Ergonomics.

General Terms
Human Factors; Measurement

Keywords
Driver distraction, cognitive workload, mental workload, visual measures, subjective measures, visual-manual in-car tasks.

1. INTRODUCTION
Saccadic peak velocity [3], percentage of fixations that fall within the road centre area (Percent Road Centre, PRC) [6], as well as pupil diameter [2] [5], have all been proposed to be sensitive for variations in the levels of mental workload in different task environments. As a part of two larger driving simulator experiments focusing on driver distraction, we analyzed the relationship of subjectively reported levels of mental workload (NASA-TLX [4]) and the levels indicated by the three visual measures of mental workload (saccadic peak velocity, PRC, pupil diameter).

2. EXPERIMENT 1 – VISUALLY GUIDED VOICE COMMANDS
In Experiment 1, we studied the comparative distraction effects of two verbally commanded in-car infotainment systems. The difference of interest between the two systems was the visual guidance provided by the other system, i.e., the available commands per application were shown for the participants in the other group. Even if the in-car system was commanded verbally, the participants had to glance the in-car display in both groups in order to navigate to the correct page in the menu showing the target application (by saying "next" or "back"). An application took voice commands only when visible at the in-car display. This was explained to minimize errors in command recognition.[1]

2.1 Method
The experimental design was mixed factorial design with 2 x 2 factors (group [Visual guidance vs. No visual guidance]) x trial [baseline driving vs. dual-tasking]). 24 volunteer university students participated (12 male, 12 female). They all had sufficient driving experience and normal or corrected vision. The participants were divided into two groups of 12 (Visual guidance vs. No visual guidance).

The experiments were conducted in a fixed-base medium-fidelity driving simulator in the University of Jyväskylä (Figure 1). Remote eye-tracking system SMI RED 500 Hz was calibrated to the front view of the driving scene tracking the participants' gaze at the driving scene. A city environment was used in practicing the driving where as a rural two-lane road environment was used in the experimental trials. Wizard-of-Oz method was used for imitating the voice command controls of the infotainment system of which menu was displayed at 21.5" Dell touch screen display.

Figure 1: The driving simulator with HUD meters and the remote eye-tracking device above the steering wheel

[1] Due to confidentiality issues further details of the user interfaces are not described here.

The orders of the trials (baseline, dual-tasking) were varied and counterbalanced within groups. In total, a participant completed 12 different in-car tasks while driving in the dual-tasking condition. In the driving task, their task was to keep the right lane as well as maintain vehicle speed between 40 and 60 km/h.

Here, we analyze only the measures related to mental workload: the mental demand scale on NASA-TLX, saccadic peak velocities, percentage of fixations towards road centre (PRC), and pupil diameters. PRC was defined as "*the percentage of gaze data points labeled as fixations that fall within the road centre area, where the road centre area is a circle of 8° radius centred around the driver's most frequent gaze angle*" according to [1]. Saccadic peak velocity and pupil diameter data were provided directly by SMI's analysis software (BeGaze). It's important to note that these metrics were calculated only for the captured gaze data on the driving scene (i.e. it did not include in-car fixation data).

2.2 Results

No significant between-subject effects were found with the metrics reported here. The participants reported significantly higher mental demand for the dual-tasking trial than for the baseline driving trial (Figure 2), $F(1,20) = 37.792$, $p < .001$.

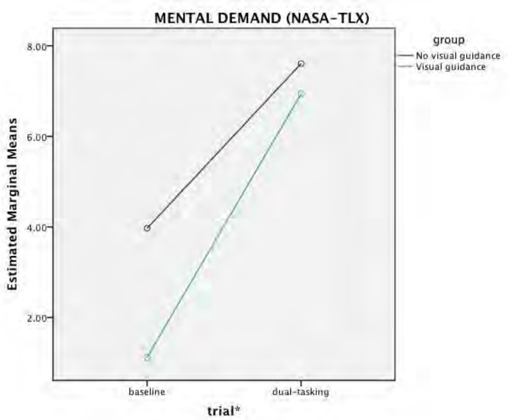

Figure 2: Subjectively reported mental workload (NASA-TLX, M, max 20) in Experiment 1 by trial and group

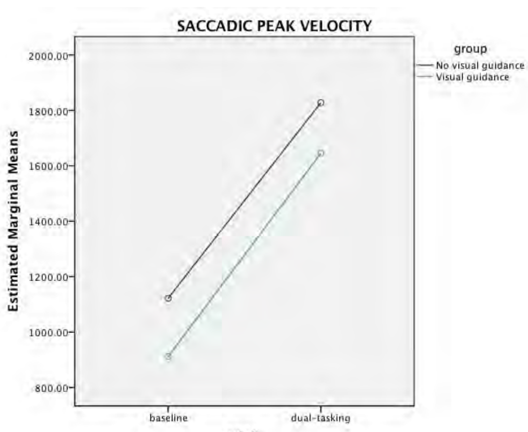

Figure 3: Saccadic peak velocities (M) by trial and group in Experiment 1

Saccadic peak velocities indicated also a significant effect of trial, $F(1,19) = 38.154$, $p < .001$, but the direction of the effect was the opposite than expected (Figure 3). According to theory [2], higher mental workload should be associated with lower saccadic peak velocities. PRC indicated also a significant effect of trial (Figure 4), $F(1,22) = 11.158$, $p = .003$. Again, PRCs were lower for the dual-tasking condition, indicating lower mental workload than in baseline driving, the opposite result to that of NASA-TLX.

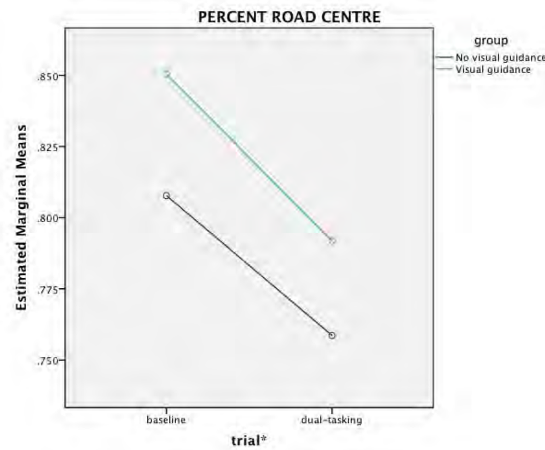

Figure 4: Percent road centre (M) by trial and group in Experiment 1

Pupil diameter did not indicate significant effects but the difference between baseline driving and dual-tasking approached significance (Figure 5), $F(1,21) = 4.083$, $p = .056$, again for the favor of dual-tasking (i.e. lower mental workload).

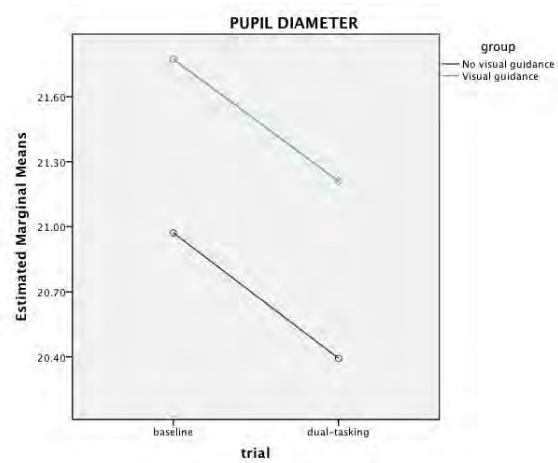

Figure 5: Pupil diameter (M) by trial and group in Experiment 1

3. EXPERIMENT 2 – VISUAL-MANUAL IN-CAR TASKS

In Experiment 2, two special Car Mode User Interfaces (UIs) providing access to a variety of smart phone applications were compared for their possible distraction effects. The differences between the UIs are not the essence here and will not be discussed.[2]

3.1 Method

Experiment 2 had almost identical setup as Experiment 1 with the exception that a smart phone placed at a dashboard holder was used for the in-car tasks. This time the in-car tasks required also much more visual-manual interaction.

The sample consisted of 20 volunteer university students (10 male, 10 female) with sufficient driving experience and normal or corrected vision. They were divided into two groups of 10, corresponding to the user interfaces UI1 and UI2. As such, the experimental design was mixed factorial with 2 x 2 factors (group [UI1 vs. UI2]) x trial [baseline driving vs. dual-tasking]). A participant completed 5 different in-car tasks while driving in the dual-tasking condition.

3.2 Results

None of the metrics reported here indicated any significant between-subject effects.

The mental demand metric of NASA-TLX revealed a significant effect of trial (Figure 6), $F(1,18) = 43.891$, $p < .001$. Similarly to Experiment 1, the participants reported the mental demand in the dual-tasking condition higher than in the baseline driving.

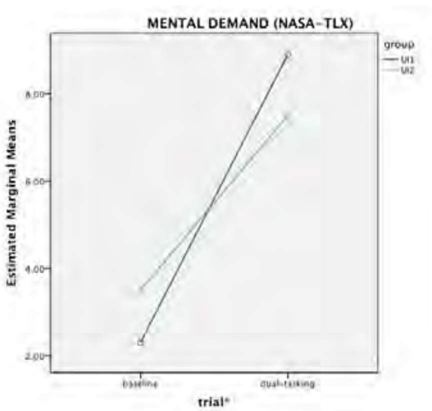

Figure 6: Subjectively reported mental workload (NASA-TLX, M, max 20) in Experiment 2 by trial and group

The saccadic peak velocities indicated no significant effect of trial but the difference between baseline and dual-tasking trials approached significance (Figure 7), $F(1,18) = 3.261$, $p = .088$. It seemed that the baseline driving would have had again the higher levels of mental workload.

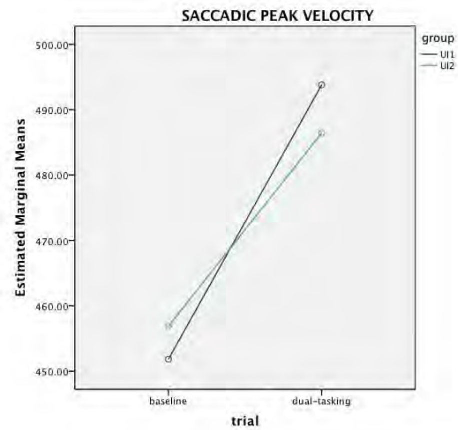

Figure 7: Saccadic peak velocities (M) by trial and group in Experiment 2

PRCs indicated significant effect of trial (Figure 8), $F(1,18) = 6.735$, $p = .018$. Again, dual-tasking seemed to lead to lower levels of mental workload. Also pupil diameters indicated significant effect of trial (Figure 9), $F(1,18) = 11.394$, $p = .003$. Pupils were again less dilated in the dual-tasking condition.

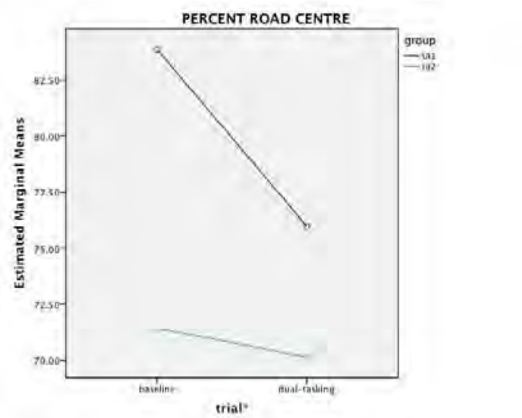

Figure 8: Percent road centre (M) by trial and group in Experiment 2

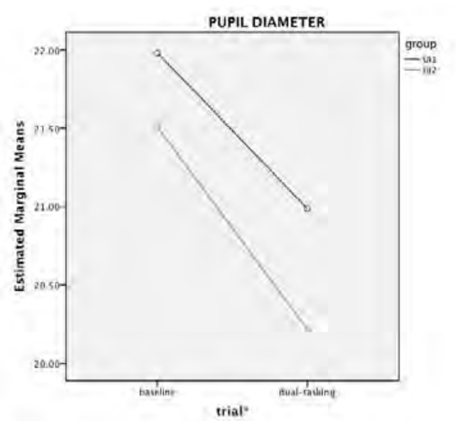

Figure 9: Pupil diameter (M) by trial and group in Experiment 2

[2] Again, confidentiality issues prevent descriptions on further details of the user interfaces.

4. DISCUSSION

In both experiments, the reported mental demand on NASA-TLX [4] indicated that the participants felt the dual-tasking condition significantly more demanding than the baseline condition. The reported average levels of mental demand were quite low in both experiments (max 20) but nevertheless the effect of dual-tasking was significant. Saccadic peak velocities indicated also significant effect of dual-tasking. However, the direction of the effect was the opposite than for NASA-TLX: the saccadic peak velocities were slower in the baseline condition, indicating greater mental workload compared to dual-tasking according to the theory behind the metric [3]. The metric of PRC indicated similar effects as saccadic peak velocities. Percentage of fixations towards road centre decreased significantly in the dual-tasking conditions. This would not be a surprise if we had analyzed all the eye-movements, including the fixations towards the in-car display. In that case, with increasing in-car visual demands the percentage is actually expected to decrease [4], but then we would not be measuring mental workload but visual load of the secondary task. However, we included into the analyses only the gazes towards the driving scene. Also pupil diameter indicated similar effects than the other visual measures of mental workload, to opposite direction than NASA-TLX. Pupil diameters seemed to decrease significantly in the dual-tasking conditions compared to baseline driving. Again, this was unexpected finding because pupil diameters should increase with higher mental workload [2].

There are a couple of features in the current experimental designs that could explain the unexpected results. The simplest explanation is that the participants actually had to put more mental effort to the baseline driving than in dual-tasking but were not able to report this. For some reason, they actually reported the opposite. However, this is an unlikely explanation because 1 (driving task) + 1 (in-car tasks) is typically more than 1 (driving task). NASA-TLX as well as other performance data not reported here seems to indicate this was the case also here. Technical problems with the eye-tracking system could provide another explanation but the calibrations were done carefully and it does not seem likely that there would have been significant effects with three different metrics even if there were some systematic technical error in the measurement.

Instead, it is possible that the interplay of eye-tracking only the gazes at the driving scene and the visual demands of the in-car tasks caused the observed effects, but because of different reasons for the different metrics. For the saccadic peak velocities, one can speculate that the saccades to and from the in-car display are included in the analysis for the dual-tasking condition, and because the participants tried to minimize the eyes-off-road time, the saccadic peak velocities are very high for these saccades. For the PRC metric the explanation could be the HUD speedometer located outside of the road centre but still on the driving scene. It is possible the participants had to make more glances at the speedometer in the dual-tasking condition to check the speed after each in-car glance. The larger drop for the UI1 than UI2 visible in Figure 7 could provide evidence for this explanation because of the greater visual demands of UI1 (not reported here), even if the difference did not become significant with these sample sizes (n=10). The more glances to the in-car display, the more inspection of the speedometer. The larger size of the average pupil diameters in the baseline driving could be explained, not by increased mental workload, but instead by the increase in illumination and/or closer viewing distance when fixating at the in-car display. Even if the in-car glances were not included in the analyses, these factors can reduce pupil size, and after fixating back at the driving scene it could take some time for the pupils to adjust. In other words, the dual-tasking data could include fixations with decreased pupil size due to delays in adjustment for changed brightness or viewing distance.

In all the three highly speculative explanations suggested above, the main source of measurement error is the visual demand of the in-car tasks and the corresponding eye-movements between the driving scene and the in-car display (as well as the HUD speedometer). Overall, the results suggest that the visual metrics indicated effects of dual-tasking likewise the subjective ratings but the direction of the effects were opposite. It is suggested that the proposed visual metrics of mental workload might reflect in this case the influence of the visual demands of the secondary task on an in-car display instead of mental workload. Thus, we suggest that the effects of visual secondary tasks should be carefully considered before making assumptions on mental workload when using visual measures of cognitive workload in multitasking experiments with visual in-car user interfaces.

5. ACKNOWLEDGMENTS

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On the track: Comparing Distraction Caused by Interaction with Tertiary Interfaces with Cars on a Test Track

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ABSTRACT

To understand the qualities and downsides of current multi-functional in-car HMIs, we are in the process of developing a study approach that allows us to assess these systems holistically. One of the major focus points of the approach is the measurement of distraction caused by visual load. Trying out the approach, we conducted two studies described in this paper, comparing three in-car systems each. In the description of the studies we focus on the visual distraction as one part of our results, besides subjective workload measures. We found differences in terms of visual load between the systems, but even more between single tasks. Additionally, we found different patterns of distraction. Some systems were more distractive than others, but over a shorter period of time. Based on our experiences in the studies we raise open questions how to handle differences in visual distraction caused by the systems when interpreting the gathered data. The main questions are concerning what an acceptable amount of distraction is and how a balance between fast and highly distractive and slow but less distractive task conduction can be found.

Categories and Subject Descriptors

H5.m. [**Information interfaces and Presentation (e.g., HCI**]: Miscellaneous

Keywords

Automotive User Interface, Evaluation, Visual Distraction

1. INTRODUCTION

In the field of Automotive HMI development it is challenging to compare the quality of various automotive user interfaces in terms of safety, performance, usability and workload aspects. In-car systems vary in their functionality, they provide different interaction modalities and the aesthetic design can be perceived highly different by people with different tastes. Likewise the appearance can be different: in one car a huge screen dominate the design or in another car all attention is directed to a central rotary device. It is further immanent that driving situations and its contextual parameters (e.g., weather, type of road, daytime) in which a system is used can also be very different. Thus, a general research questions is: "How can we compare the distraction caused by different automotive user interfaces in current cars from various manufacturers?".

We aim at developing an approach that allows a comprehensive assessment of the cognitive load caused by automotive user interfaces and its distraction from the driving task. The intended method package is supposed to built on already established approaches and combines and extends the features of best practices with findings from our recent research in automotive interface evaluation. For that we are working towards a test procedure with defined and comparable tasks and exact methods of measurement regarding workload, distraction, driving performance and task completion time. The aim is to develop a test procedure, which is straight forward and easy to reproduce by the automotive industry and related organizations. Test procedures already exist for in vehicle tasks, such as the SAE J2365 [1], which focus primarily on the navigation task. We nevertheless believe that it is necessary to study complex modern tertiary systems in their entirety, since these systems allow so much more interaction than the conduction of navigation tasks.

It is our goal to provide an approach for investigating in-car HMIs holistically. For that purpose we developed a list of foci, based on a review of related literature, such as efficiency, effectiveness, accessibility, user experience, qualities under dynamic context conditions, and distraction, besides others. For that purpose our approach combines appropriate qualitatively and quantitatively methods to investigate the aspects of systems, one of which is the distraction it causes from the road.

This paper focusses on the distractive potential of HMIs through their visual load, which is definitely one of the most important aspects of a system, since it affects safety directly. Additionally, we describe the subjective workload measures we used and the results we gained from these measurements. This position paper describes the first steps in our iterative approach along with two example studies, in which we applied the approach in order to inform its further development. Finally, it raises open issues that we discovered concerning researching cognitive load and distraction, as important part of our approach. These issues are what we want to raise within the workshop, to discuss them and to gather input from the community on how to potentially solve them, so that the development of our methodological framework can progress further. Although our work focusses mainly on visual load, we believe that the issues we raise also contribute to the cognitive load discussion. Especially the dispute between having a high load over a short period of time and a lower load over a longer period applies to both visual and cognitive effort.

2. APPROACH

In order to compare the distraction caused by different automotive user interfaces in current cars from various manufacturers, several challenges have to be addressed. In the following we will describe our approach by means of a user study:

In a first step we analyzed, which tasks should be given to participants in order to study tertiary in-car systems as holistically as possible. We identified four main groups of functions to be representative for each system, which therefore should be in the focus of our investigation: *navigation*, *entertainment*, *communication* and *configuration*. Since most current systems group functions accordingly, example tasks from each functional group were selected. These involve typing in a navigation destination, selecting a radio station, calling a number from the phonebook, and changing audio settings in the vehicle. The tasks were chosen since they represent a typical feature of each functional group and are therefore available in all modern in-car systems.

For investigating the distractive potential of each task, we ask participants to conduct them while driving on a test track. To reduce the effects of a first time usage, all tasks are trained once while the car is parked before they are conducted and recorded while driving. While this might not sufficiently reflect the experience users have with systems after using them for a longer period of time, our approach did not allow for a longer training phase.

For the driving task we propose the usage of a test track for several reasons: It increases safety and makes the conduction of an experiment easier, since all equipment can be stored at a central location. Additionally it allows a controlled experiment, with environmental conditions being relatively stable. The test track on the premises of our industrial partner represents a circle of 64 meters in diameter with an integrated part shaped like an "eight", which allows changing the direction of the curve that is driven (Figure 1).

Figure 1: Test track used in both studies.

Speeds up to 50 km/h are safely possible in trial conditions. Driving in a circle represents an easy and reproducible, nevertheless not undemanding driving task, which could be established as a standard for testing car interfaces while in motion.

To measure the distraction caused by the visual load affected by interacting with tertiary systems in the vehicles we use eye tracking technology, recording the eye movements between road and systems. Additionally, we used self reporting tools to give the participants the possibility to express their own perception after the trial.

3. STUDIES

The following paragraphs describe two studies we actually conducted with the above mentioned approach. The aim of the description is not to reveal all details of the results, but to focus on findings that are interesting to present to the community, not so much as finished results but in the form of challenges that we currently face. These findings form topics that we believe pose valuable issues for discussion in a workshop dealing with cognitive load.

3.1 Study 1

The goal of the first study was the comparison of three state of the art centralized in car systems on sale by German automobile manufacturers in May 2011 (BMW iDrive, Audi MMI, Mercedes COMAND). The three systems consisted of a central screen and a rotary knob with additional buttons to interact with the menu and functions shown on the display. The main differences of the systems are the menu structure and logic, the mapping of the rotary knob with menu functionality and the usage of context keys. For the study we invited 12 users, split evenly into three age groups of four people each (Group 1: 20y - 35y; group 2: 36y - 50y, group 3: 50y - 65y). Each of the groups consisted of two women and two men. We chose a within subject design, each user therefore operated each vehicle and system. Participants conducted tasks from the groups mentioned above, namely navigation, communication, entertainment, and settings.

Within our sample, we found high differences in the mean task duration, tasks conducted with the BMW system took on average 51.16s (SD: 29,1s), while the tasks with the Audi required 65,98s (SD: 39,7), resulting in tasks with the BMW only requiring 72% of the task duration required for the Audi system. Especially remarkable were the differences in the radio task (Audi: 43.22s, SD: 66s; BMW: 25.93s, SD: 25.4s) and in the phone task (Audi: 55.22s, SD: 28.4s; BMW: 35.14s, SD: 22.9s)).

Overall the eye tracking data showed a high level of distraction caused by all systems, with visual attention being directed on the system about 50 percent of the time (Audi: 49%, BMW: 54%, Mercedes: 53%). In combination with the task duration we computed the lowest eyes of the road time during the task conduction with the BMW system.

What left us with open questions was that we found that participants had the highest mean gaze duration on the display (Audi: 0.94s, SD: 0.34s; BMW: 0.99s, SD: 0.34s; Mercedes: 0.85s, SD: 0.23s) while conducting tasks with the BMW iDrive system. Nevertheless, the total eyes of the road time was the shortest with the BMW system due to its short overall task durations. The BMW system therefore was more distractive while the tasks were conducted, but less distractive in terms of overall eyes off the road time. Tasks were simply faster to conduct, which reduced the overall distraction.

We after conducting tasks with each system, we handed out the NASA RTLX questionnaire, which is based on the TLX scale by [3], to the participants. On the scale from 0 - 100 the systems got the following ratings: (Audi: 28.8, SD:17.8; BMW: 25.7, SD:13.4; Mercedes: 37.9, SD: 24.2). Similar to the eye tracking data, the TLX shows that the BMW system caused the lowest workload on the user side. What differs to the eye tracking interpretation is the fact that the overall task load with the Audi system was seen to be lower than with the Mercedes system.

3.2 Study 2

A second comparative study was conducted in spring of 2012. The study goal was again to compare interactive in-car systems and their effect on distraction. This time we compared three european compact class vehicles (Volkswagen Golf VI, Opel Astra, Ford Focus). Again we chose tasks out of the four functional groups of the systems (Navigation, Entertainment, Settings, Communication). Distraction was again measured with an eye tracking system. Different to study 1, we also included a mobile navigation system (TomTom) in each the three cars to compare it to the built in systems (see Figure 2). In study 2 we choose a between subject design, inviting 36 participants, 12 for each car. Participants were balanced in terms of gender and divided into three age groups (20-35, 36-50, 51-65 years old). The between subject design was chosen to minimize participant burden. In study 1 one test lasted up to four hours for each participant leading to exhaustion.

Figure 2: Volkswagen Golf VI cockpit equipped with mobile navigation system and eye tracker.

Summing up all tasks the Volkswagen system allowed the fastest average task completion time (VW: 44.31s, SD: 31.8s; Opel 46.02s, SD: 48.47; Ford 53.7s, SD: 52.6s). When analyzing the time, in which users on average focussed their visual attention on the displays, we found that although tasks could be conducted faster with the VW system they lead to more eyes of the road time than tasks with the Opel system (VW: 26.55s, Opel 22,95s, Ford 31.18s). In terms of eyes off the road, the VW system therefore distracted the users more, than the Opel system. Tasks with the Opel system took longer, but could be conducted with much shorter gazes (compared to the VW system). Therefore the distractive episodes were shorter and attention to the road could be paid more often and for a longer time. This was supported by shorter average duration per gaze with the Opel system compared to the others (VW: 0.81s, Opel: 0.71s, Ford: 0.87s).

It is important to note that the distraction caused by the systems strongly varied over all tasks. Thus, differences in the control design and philosophy become apparent (e.g., touchscreen vs. rotating knob). The VW system (touch screen) allowed a much faster conduction of the navigation task (i.e. type in letters), scrolling lists was nevertheless much easier with the Opel system (rotary knob).

We compared the built in systems of the Volkswagen, Opel, and Ford with each other and with a mobile TomTom navigation system to asses how distractive the mobile system was compared to the built in ones. Since the mobile system only supported the navigation task (type in a destination) we could only compare values form this tasks over the systems. We found that the navigation task was on average faster to conduct with the mobile navigation system (TomTom: 75,94s, Cars: 112,4s). This also lead to a lower duration of eyes of the road (TomTom: 43.15, VW: 56.61, Opel: 57.87, Ford: 77.74). Nevertheless, the average glance duration was longer than with the built in systems, resulting in a higher distraction during the phases of interaction for a task. The average glance duration during the navigation task with the Opel system, for example, was 0.77 seconds, with the mobile navigation system a glance on the screen took 1.16 seconds on average. The causes for this difference remain unclear, one cause could be the mounting position on the windshield, that required more effort in hand-eye coordination when reaching over for an input, but in the same moment allowed the users to keep the eyes on the system for longer, since the could see the road behind the navigation system.

In study 2 we asked the participants to rate their subjective experienced effort on a self assessment scale after they completed a task. The scale reaches from 0 to 220, participants tick a certain point on the scale based on their perceived effort, low ratings are representing a low effort. Comparing the three cars tested regarding the subjective experienced effort of conducting the different tasks, no significant difference could be found (VW: 38, Opel: 45, Ford: 44). Certainly, it can be stated that the navigational task with the Opel system (mean: 104) led to a marginally higher experienced effort in comparison with the VW system (mean: 56) and the Ford system (mean: 83). Regarding the other tasks, no further significant differences could be found regarding the subjective experienced effort of the three systems.

4. DISCUSSION

Both studies left us with the open question: “Is a higher level of visual load and distraction for a shorter moment more or less beneficial than a lower load over a longer period of time?” We are aware that there is not one right answer to that question and that there will be boundaries, in between one answer might be better than the other. But where are those boundaries? Is it the 2 second per glance rule or the rule that a task should not last longer than 25 seconds [2]? We perceive this question as highly relevant for our design activities in the automotive field, having to decide whether to design for a fast but potentially more demanding, or slow and less demanding conduction of tasks.

Our findings in study 2 show this conflict, resulting from different choices in input modalities. The touchscreen interface of the Volkswagen allowed a faster conduction of the tasks, but due to the necessary hand-eye coordination and the bad responsiveness of the screen, glances lasted longer and therefore the distraction in each moment of the task was higher then with the other systems. The same is true for the mobile navigation system, which allowed the tasks to be conducted faster, but was more visually demanding during the interaction. Based on our two studies we hypothesize that the touch screen interfaces we investigated were more efficient, but more demanding than the ones using a rotary knob or directional pads.

As stated by Green [2], rules like the 15-seconds-rule can be applied to tasks and systems, that have similar characteristics to the navigation task, that the rule was developed for. However, it can not be applied to any tasks. We therefore see a necessary discussion on what is acceptable in terms of workload and distraction, based on the kind of task. Differences in task concern the frequency of their conduction, the immediacy in which the task has to be conducted, and so on. Or is it, as Green suggests, the total eyes of the road time, which has to be taken into account. We nevertheless argue that a maximum of 10 seconds off the road time could also result in systems, that cause a constant distraction from the road over 10 seconds, without braking the rule.

We were also struggling with the fact, that the tasks for each car were very heterogenous in terms of distraction. Our data clearly showed, that no system was superior to the other throughout all tasks. One could argue that already a single task, that brakes established rules, makes a system unacceptable. This argument is supported by the finding that not only the average visual distraction should be considered but unusual exceptions in response to a traffic situation should be taken into account, since these are more likely to cause crashes [4]. Another opinion could be, that some functions, which were identified to be most distractive, should only be possible while the car is parked. But would that not lead to even more distraction, caused by user frustration and uncertainty, which functions are available in which situation? Other studies of ours have shown, that users would simply switch to using their smartphones, if the requested functionality is not available on the in-car system.

We also found that users experienced the workload caused by the tasks as less intense than the eye tracking data shows. In fact, all task load ratings are relatively low given the fact, that users were distracted from the road more than 50% of the task time. We can conclude that the perceived workload with the evaluated systems may be lower than the real workload, potentially leading to a dangerous gap between perceived and real risk of system usage.

Finally the question has to be raised whether the driving realism with the test track is sufficient for making statements about the distractive potential of in-car interfaces. Users were driving in a constant circle and could follow the track without much load caused by the driving task. No unexpected events were to occur, a safe driving style on the test track therefore could be maintained without a high amount of attention on the track. We therefore suspect that tasks were completed faster than under normal driving conditions. On the other hand our study ignored the concept of plastic time [5], meaning that interaction with in car systems can be interrupted and resumed, based on mini episodes during a trip (e.g., stopping at a red light). The way tasks were conducted in the experiment, therefore might not have represented the way users would conduct the in-car tasks in reality.

5. SUMMARY

In this paper we presented an approach we use to compare different in-car HMIs based on their usability, the user experience they cause and how they distract users from the main driving task. We propose the usage of example tasks from the areas of navigation, communication, entertainment, and configuration. Focussing on the distraction from the road, which we measured, we presented two studies in which we compared the multifunctional interfaces of three currently available cars each. We found differences between the vehicles, which allowed a statement about the distraction caused by each system, in comparison to the others. Nevertheless we were left with open questions. The main open question concerns the conflict between tasks, that are fast to conduct but more distractive and task that last longer, but distract less in every moment. Additionally, we were confronted with the question which level of distraction can be considered as acceptable and how to deal with systems, which provide functions that are beyond that acceptable range as well as functions, that follow established rules like the 15 second rule.

Since we are constantly refining our study approach as well as the interpretation of measured data, which is an important aspect of proposing a study concept, we would like to discuss these issues in the workshop with other members of the community. We believe that this would help us to direct our future efforts in understanding distraction caused by visual load in the vehicle.

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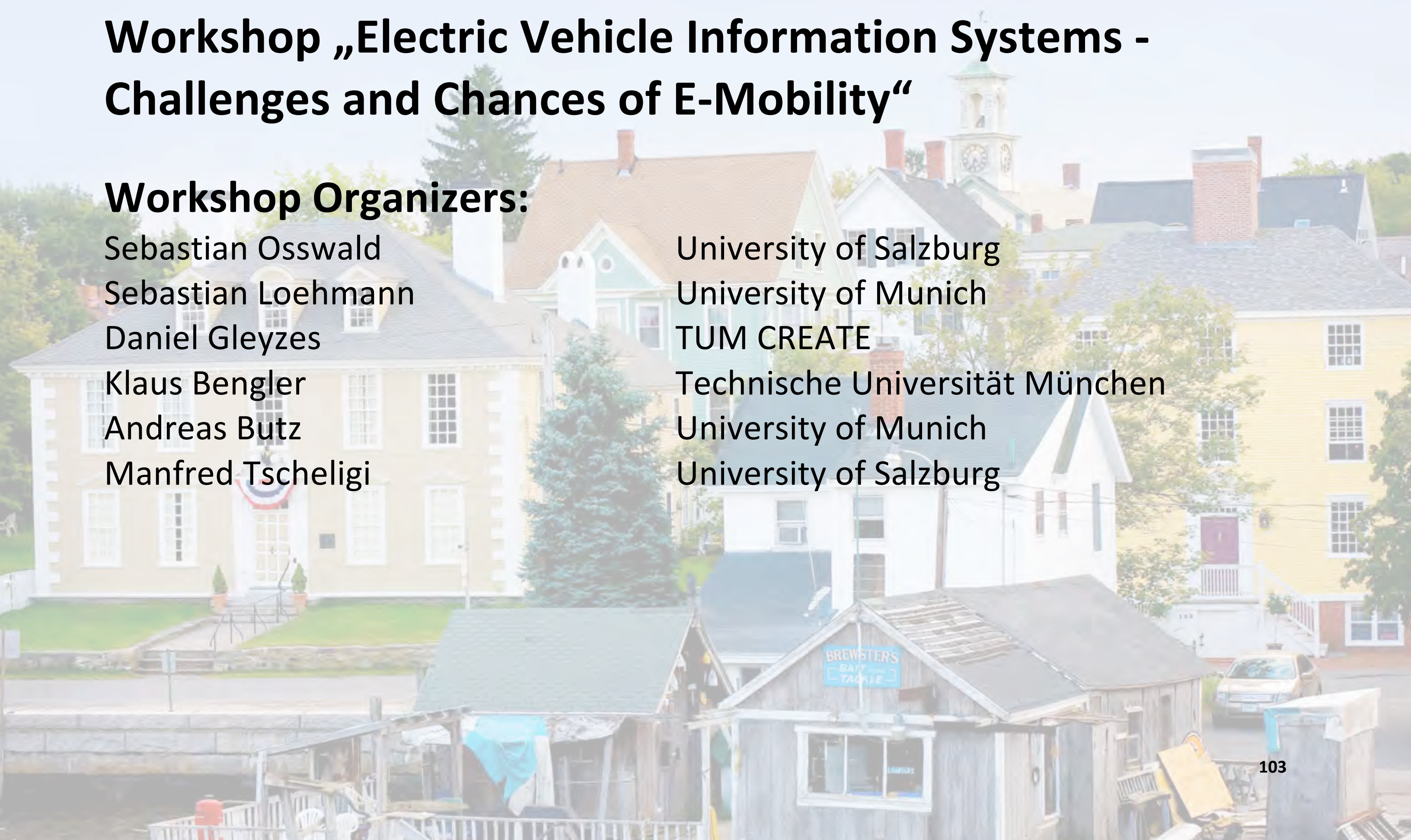
Workshop „Electric Vehicle Information Systems - Challenges and Chances of E-Mobility“



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Electric Vehicle Information Systems (EVIS): Challenges and Chances of E-Mobility

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ABSTRACT

What would the interaction with an automotive user interface in an electric vehicle (EV) look like? In this workshop we will discuss how in-vehicle information systems (IVIS) and car interiors can be designed to meet challenges inherent in the development process of electric vehicles like e.g. range anxiety, energy recovery/recharging or automated driving. In accordance with the fundamental changes shown in today's EV concepts, we address the challenge of rethinking in-car interaction as well as interior design to overcome traditional implementation habits and see how EVs differ from contemporary cars. We want to open up the stage for new interaction techniques and flexible interior designs that embrace the future requirements of EVs.

Keywords

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

1. INTRODUCTION

Much effort is put into the development of sustainable batteries for electric vehicles (EV), the conceptualization of electric motors and the development of a smart grid to provide a working infrastructure for an e-mobility future. Although the car as a design space has been identified in Human-Computer Interaction (HCI) [5], most researchers and professionals have mainly been focusing on state of art vehicles with combustion engines and do not address electric vehicles. Given the continuous progress in system development and infrastructure for EVs, one of the neglected issues appears to be that barriers of adoption in driving an EV persist. EVs differ in terms of how they are driven, how they sound or how they are refuelled. The mobility behaviour is further affected by the remaining vehicle range and the availability of charging stations.

We as researchers, designers and practitioners in this design space thus need to be sensitive to influencing factors such as acceptance, safety, distraction or anxiety that form barriers for driver adoption. Following a user-centred design process for an EV it is inevitable to consider user requirements and interaction concepts early and especially pay attention to the development of novel information systems. As information systems in electric vehicles (EVIS) are the connection between the user and the car, interfaces are the main channel to translate the characteristic of an EV. EVIS transport meanings and messages to both, the driver and the system itself and communicate the meaning and behaviour of certain functionalities that differ from what is already known about state of the art vehicles.

In a rising field of research and development like e-mobility, there is especially an opportunity to early transfer knowledge into the design process and to iteratively accompany the technology-centred development process. There are great possibilities and challenges for what interaction-driven approaches involving natural or multimodal user interfaces [2] can contribute towards reducing driver distraction [7], predicting driver behaviour [6] or assists in critical situations [8] to acquainting the future target group with new features and tools inside an EV. Additionally, there is also a chance to transfer already established energy-saving or energy-providing concepts [4] from other areas (e.g. households) into the automotive context.

One of the decisions made by original equipment manufacturers nowadays is to follow a conversion or purpose design approach. Conversion design is a possibility for manufactures to use what is already there and to fit what is new into a given structure. In the area of EVs this means that batteries, the electric motor and new in-vehicle information systems (IVIS) are integrated into a state of the art car with its existing electronics and systems designed for conventional powertrain. Purpose design on the other hand is aimed at creating and developing a whole new car in respect to the requirements of its electric parts. Regarding advantages and disadvantages of both approaches, it is intensively debated among designers and engineers in the automotive sector whether to design EV concepts in a traditional way or to risk an unconventional approach. Following a purpose design approach for EVIS would therefore mean to basically design their appearance and features according to a changing interior, to consider the EV properties in the interface design and create applications and interaction modalities to support the driver in handling the EV.

To overcome traditional implementation habits regarding modality placement, interface arrangement and design as known from state of the art conversion design approaches, it seems to be useful to take a closer look at the area of automotive purpose design approaches. We believe that this is a remarkable advantage for the development of novel information systems, but we also see that there will be a longer period of conversion design. The development cycles in the automotive sector are slow, as cars need to be designed and produced in a sustainable, cost-efficient way and also need to meet the market and legal requirements. It is therefore already predictable that there will be adapted car concepts in the future, which also require new information systems. In this workshop we will therefore address both, the target area of conversion design as well as purpose design.

We acknowledge that the spectrum of automotive user interface research is wide and broad, but referring to electric vehicles only little research has been conducted so far. Aso et al. [1] conducted early research concerning the process of designing an EV interface. They proposed a method that aimed at driving an electric car by using an electromyography (EMG) interface. The conducted study reports on the measurement of EMG signals from both hand palms and the neck using a simple electrode. The effective frequency band of the EMG signal was extracted and converted into binary signals to drive an electric car. As a result, they stated that the effective frequency band influences the operation feeling and riding comfort.

Dealing with plug-in hybrid electric vehicles, Gerding and colleagues [3] raised the question about how to coordinate EV charging in order to accommodate capacity constraints. They designed a novel online auction protocol, where vehicle owners use agents to bid for power and also indicate time windows in which a vehicle is available for charging. The mechanisms provide higher allocated efficiency and can sustain a substantially larger number of vehicles at the same per-owner fuel cost saving than a simple random scheme. Strömberg et al. [9] on the other hand focused already on a few of the issues regarding EV human-machine interaction. They evaluated two concepts for an EV instrument cluster to gain knowledge on which information is relevant to the driver and how information should be presented.

2. OBJECTIVES

It is the aim of this workshop to address the following goals:

- Identify properties of EVs that affect driving behaviour/needs for novel interface/interaction approaches.
- Transfer EV properties into design concepts that embrace areas like multimodality, natural user interfaces or interaction concepts.
- Consider a change in driving behaviour of the EV (e.g. acceleration, recuperation) as well as new concepts of e-mobility driving (e.g. mono driver cars, car sharing).
- Discuss user interface design issues for EV information systems.
- Address novel techniques of information representation that persuade, support or warn the driver related to EV-specific information and attributes.
- Discuss challenges associated with HCI and hardware/software development in the car.
- Identify key themes for developing a framework for user interfaces in EVs.
- Develop a network to discuss studies that aim for evaluation of e-mobility related issues.

3. AUDIENCE AND ORGANIZATION

We aim to address and gather both, academics and practitioners within the field of automotive research, design and engineering. The workshop is intended for: HCI researchers in general, who are interested specifically in the automotive context; experts from the field of human-computer interaction, computer science, social science and psychology, who are willing to identify challenges and goals for the specific characteristics of electric vehicles; automotive user interface designers and engineers from a scientific and from an industrial perspective; practitioners from OEMs, automotive industry suppliers and from other related field of industrial expertise, who want to explore the challenges of e-mobility.

The workshop's website provides information for participants as well as results and impressions from the workshop and can be reached via *evis.hciunit.org*. Further, the accepted position papers are made available on the website.

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Prototyping A Mobile Routing Assistant for Optimizing Energy Scheduling and Charging of Electric Vehicles

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ABSTRACT
In order to increase the consumer acceptance of electric vehicles (EVs) and to enable an efficient operation of charging station networks, we argue for an intelligent routing service to assist EV drivers in searching and reserving public charging points. In this work, we present out ongoing user-centered research towards a generic reservation mechanism for a smartphone-based routing assistant. We describe fundamental use cases to be covered and outline basic thoughts and experiences from the design process. The main contribution is an interactive prototype which is based on standard Web technologies and thus can be accessed from various mobile platforms for experimentation. Besides using the prototype for early user tests, we plan to finally connect it to our functional server-side routing platform and run a field trial to assess the benefits of such a reservation and routing concept for drivers in a real-world setup.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Graphical user interfaces (GUI), Prototyping.*

Keywords
Electric vehicle, mobile app, e-charging station, reservation

1. INTRODUCTION
Despite the huge potential of electric vehicles (EVs) for reducing greenhouse gas emissions and optimistic predictions on their market penetration, today's actual sales are still low compared to traditional gasoline-powered vehicles. Besides the currently high price of EVs, concerns regarding the required public infrastructure and necessary changes in the personal driving behavior might discourage the faster adaption of such vehicles. Recharging the EV battery can last from 10 minutes (quick charging) up to several hours. Firstly, due to the relatively small range of EVs of approx. 100 km, a phenomenon called range anxiety [3] may prevent users to fully exploit even this reduced range. Secondly, the offering of recharging stations in urban areas in park houses, at gas stations, in shopping malls, on the street, etc. will become quickly unmanageable while their actual availability at the time of arrival is unknown to the driver on the move.

The Austrian project KOFLA [10] investigates a suitable service platform for supporting EV drivers in finding and making reservations for public charging stations. The basic idea is to have a central broker that brings together EVs requesting recharging energy, and recharging stations that have free recharging capacity (energy, parking places, etc.). Such a brokerage engine will offer benefits for each of the stakeholders involved in the EV charging process:

- The *EV driver* will be directed to an available charging station close to his actual destination. At the same time, an intelligent scheduling algorithm avoids overloading of the grid and thus allows for arbitrary charging times. The expected result is a higher acceptance of EVs since charging is possible even during peak load periods in the energy grid.
- The *charging point provider* will benefit from a better utilization of his infrastructure since the demand can be anticipated and the charging resources planned well in advance.
- The *energy grid operator* gains valuable information for energy balancing and thus is not confronted with unexpected high loads caused by charging EVs. Additionally, collected usage data can be used for further planning of the recharging infrastructure both for the grid operator and the owner of charging points.

As we presented the results of initial mobility studies and simulations for defining the actual requirements, load balancing and scheduling concepts and implementations, as well as a suitable system architecture for realizing the proposed services in previous publications in [1] and [2], the present work focuses on the prototyping of a mobile assistant for giving EV drivers comfortable access to the platform services. We describe the ongoing work on a respective application for smartphones. We deliberately target no all-in-one solution covering the entire charging process (e.g. including payment features, etc.) but focus on a generic reservation concept. In the following, we give an overview about related work on optimizing the EV charging infrastructure and supporting EV drivers through mobile applications. We then introduce the identified use cases and present the development of our interactive Web-based application prototype for user tests.

2. RELATED WORK
Several recently presented research works are concerned with preparing suitable charging infrastructure, estimating the impact of EV charging on the energy grids and with investigating approaches for energy scheduling and load balancing to cope with expected high numbers of EVs.

For example, Chen et al. [5] analyzed real-life parking information in Seattle, US and determined common parking locations and durations for installing a restricted number of charging stations across the city. Lopes et al. [12] analyzed the behavior of the low voltage grid and the changes in the global generation profile considering different levels of EV penetrations to determine the maximum share of EVs current energy grids may bear. In a similar vein, Clement et al. [4] and Verzijlbergh et al. [14] explored the impact of EV charging for residential low voltage networks and showed that a significant number of transformers will be overloaded if no charge control is applied. Based on simulations and a case study, Sánchez-Martin and Sánchez [13] suggest a consumption control management system to deal with the battery charging at parking garages with plug-in EVs. None of these research projects considered mobile applications for EV drivers to collect data about charging needs and thus to estimate upcoming demands on the energy network. One of the rare respective examples making use of a mobile application is the work by Mal and Gadh [11]. Their framework for enabling aggregated scheduled charging of EVs includes an app for monitoring and controlling the charging of vehicles. However, also this solution does not make use of a reservation mechanism as proposed in this paper.

More generally, a series of applications for smartphones is currently available from different software distribution platforms to support (potential) EV drivers. Respective mobile apps include advisers such as *iEV2*[1] and *eMotionApp*[2] which analyze their users' mobility behavior and needs and help them decide whether to buy a private EV. Other EV apps are directly provided by car manufacturers and act as remote controls for specific functions of the vehicle, allow viewing status information such as the current state of charge (SOC), or provide statistics on environmental contributions such as greenhouse gas savings. Examples include *Volvo C30 Electric*[3], *Nissan LEAF*[4], *smart drive*[5], and *OnStar RemoteLink*[6] for GM Chevrolet Volt. *GreenCharge*[7] is a more generic solution supporting GM Chevrolet Volt and Nissan Leaf.

Several apps are dedicated to searching for charging infrastructure and offer comfortable access to remote databases. Most of them follow a community-driven approach allowing the easy adding and updating of charging points by users. Popular solutions include *Plugshare*[8], *CarStations*[9], *Plugsurfing*[10], *Recargo*[11], and *ChargePoint*[12]. The latter features a basic reservation system and availability information, however, is restricted to its custom network of charging stations. Upcoming applications such as the *WattStation* app [6] by *General Electric* also include payment functionality over the smartphone.

3. USE CASES

We conducted a use case workshop with different stakeholders including experienced EV users as well as representatives from public transportation companies and energy providers. Four basic use cases could be identified for supporting an EV driver in finding an available public charging station. As mentioned above, we deliberately excluded payment functionality etc. and services requiring a wireless connection to the charging point itself. In the following, we describe the four use cases and include considerations for their practical implementation.

3.1 Specifying destination for navigation

Obviously, for providing the driver with information about available charging stations close to the destination of his tour, this location needs to be known to the application. At the same time, this address will be used for guiding the driver by a navigation system. While context-aware mobile applications may try to derive this information (e.g. by checking personal calendar entries), the safest way is simply entering the street address of the targeted destination in analogy to traditional navigation solutions.

3.2 Searching for charging stations

A suitable application needs to provide a search feature for charging stations close to the entered destination. This includes specifying several further charging parameters such as the estimated charging duration or the expected SOC after charging as well as the charging speeds supported by the car which may be configured once over a settings menu. To enable an efficient scheduling of potential reservation requests, also the estimated time of arrival needs to be transmitted.

3.3 Sending reservation request

To make sure to have an available charging station close to the destination, a driver may issue a reservation request for a particular charging point. In our setup, such a reservation request directly follows a search for charging stations. Thus, specific charging parameters are already known and the availability of the charging point was already checked during the search. In order to avoid haphazard reservations and to reduce inaccuracies in estimating arrival times and thus to enable a more accurate and robust scheduling, the introduction of a few practical constraints seem to be beneficial. These include allowing only for one pending reservation at a time and permitting reservation only within a specific time window before arriving at the specified charging point (e.g. 3 hours) and discarding the reservations of late arrived cars.

3.4 Redirection to charging station and guiding to actual destination

When a reservation request was sent and successfully confirmed by the server-side platform, the driver shall be guided to the respective charging station by traditional turn-by-turn navigation and audio signals. Since for the most cases this includes a slight redirection away from the actually desired destination, the application should also support a pedestrian navigation mode for showing the way from the parked vehicle to actual destination.

4. PROTOTYPING

Based on the use cases described above, we prototyped a respective mobile application. We started by creating several designs and simple mockups and finally implemented an interactive Web-based software prototype.

4.1 Mockups and Experiences

As first steps, we conducted simple paper prototyping and sketched screens and user interface elements. We created various design alternatives and put special emphasis on techniques to specify the reservation parameters in terms of planned parking duration and/or expected driving range after the charging process.

[1] http://itunes.apple.com/app/iev-2/id527020422

[2] http://itunes.apple.com/ch/app/emotionapp/id493864486

[3] http://itunes.apple.com/app/volvo-c30-electric/id471884606

[4] http://itunes.apple.com/app/nissan-leaf/id407814405

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[8] http://itunes.apple.com/app/plugshare/id421788217

[9] http://itunes.apple.com/app/carstations/id461066178

[10] http://itunes.apple.com/app/plugsurfing/id455198327

[11] http://itunes.apple.com/app/recargo/id405168584

[12] http://itunes.apple.com/app/chargepoint/id356866743

Figure 1. One design mockup includes a slider for specifying the charging duration and the expected range.

First mockups included a slider concept as a visually appealing way to specify this information. The variant in Figure 1 focusses on specifying the driving range with the slider. Its bar shows the estimated charging duration for the selected range as soon as the user lifts his finger. Whereas this combined slider display of range and duration seemed beneficial at first sight, we identified several drawbacks while further elaborating on the concept. First, experiments with related touch-based slider controls on mobile devices showed their inaccuracy for such fine-granular settings. Thus, we decided to go for more traditional spinner controls. Second, specifying the expected range forces the user to park his EV at the particular charging station for the calculated duration. Since we target a comfortable solution avoiding any major adaptations of users' mobility behavior and thus to increase the acceptance of EVs, we agreed to focus on the actual parking duration: drivers typically know how long their vehicle will stand at the parking spot (e.g. during a shopping tour or a restaurant visit, etc.). They probably will not change such routines and extend the parking duration to reach a specific battery level or range.

Overall, we wanted our application to be as self-explaining as possible and thus decided for a wizard-like user interface guiding the user through the different steps of making a reservation for a particular charging station.

4.2 Interactive Prototype

We implemented an interactive prototype to gather early feedback from real users in a next step. We restricted the functionality of our first prototype to the four above-mentioned use cases and focused on the actual reservation process to keep expenses for prototyping low. To make the prototype easily accessible for interested people and even allow them to test on their personal smartphone we decided to go for a platform-independent Web application. Its latest version is publicly accessible [9] and features both a mobile emulator view for desktop browsers as well as a plain variant to be accessed from mobile devices.

Our prototype is based on traditional Web technologies such as HTML, JavaScript, and CSS. For displaying maps, visualizing points-of-interest and providing a routing feature we integrated the respective services offered by the *Google Maps JavaScript API* [8] and *the Google Directions API* [7]. We made use of the *Yahoo! User Interface Library* [15] for integrating sliding and fading effects to closer resemble the look-and-feel of a native mobile application. Further, we designed some custom icons and symbols to embellish the interface.

Figure 2: Simple form for entering the destination.

Figure 3: Specifying the duration of stay.

Figure 4: The user may choose to be notified about charging stations becoming available.

Figure 5: Available charging stations in walking distance to the destination are shown on the map.

Figure 6: When a reservation request is sent, the estimated arrival time is calculated for scheduling the reservation.

Figure 7: Traditional navigation leads to the charging station while the distance of the closest charging station is shown.

Figure 2 shows the start screen of the application. The user is asked to enter the street address of his destination and confirm by touching the bottom right button. In analogy to a traditional navigation solution, the user is informed about the route length and estimated duration on the succeeding screen (Figure 3). The adjacent map view shows the area around the destination location. Additionally, the application displays the estimated SOC at the destination in form of a battery image to illustrate the charging demand. The planned duration at the destination may be entered by specifying the respective hours and minutes through the plus and minutes buttons (native mobile applications may use available spinner controls). By pushing the search button (with the magnifying glass) the application starts looking for charging stations which are available at the calculated time of arrival and are located within walking distance from the specified destination. In the current version of the interactive prototype number and locations of charging stations are locally generated on a random base.

In case no charging station is available, the driver is notified and may choose to be notified if a suitable charging station suddenly becomes available (Figure 4). Otherwise the map view is updated with corresponding markers (Figure 5) and enabled for interaction such as panning for exploring all found charging stations.

In a first design we used green and red icons to indicate the availability of charging stations with the aim to increase the awareness of totally deployed charging stations. Finally, we decided to hide the unnecessary occupied charging points and show only the available ones to reduce cluttering on small mobile displays. The current markers as depicted in Figure 5 contain information about the electricity price of this charging point as well as small symbols to indicate the plug type and whether this point supports fast charging. Preferences concerning plug type and fast charging etc. could be specified in respective configuration settings.

By touching a charging point marker, the user is asked to confirm his reservation request for the estimated arrival time and the given duration (Figure 6). When he does so, the application switches to a traditional navigation screen in bird's eye view (Figure 7) with turn-by-turn instructions (such as following the road for the next 1.2 kilometers) guiding the driver to the selected charging station. In our prototype this functionality is represented by a still image, since the implementation of such a 2.5D navigation is time-consuming and does not belong to the core functionality of the prototype. Additionally, the navigation screen shows the current SOC and the distance of the available charging station closest to the driver's current location in order to still support spontaneous charging at nearby charging points.

Since the driver is not guided directly to his desired destination but redirected to the selected charging station, the application switches from vehicle to pedestrian navigation mode guiding the user to his actual destination as soon as the vehicle has arrived at the destination charging station. This final step is not covered by the recent version of the prototype.

5. CONCLUSIONS AND OUTLOOK

In this paper we introduced our ongoing work on a smartphone-based assistant for EV drivers. The application will help to ensure the availability of a public charging station close to the driver's destination and due to more accurate forecasting enable optimized load balancing and energy scheduling for the charging point owner and the grid operator. We presented some typical use cases for the envisioned trip planning scenario and gave insights in the design and implementation of our interactive Web-based application prototype.

Our current prototype covers the fundamental reservation process, however, is a not a complete EV driver assistant yet. Besides the prototypical integration of additional features such as the mentioned pedestrian navigation mode and multi-modal routing considering public means of transport, we plan to improve the visual appearance and polish the user interface to give it a more native look. We then will conduct user tests to collect feedback and elaborate our prototype. As an important part of future work, we plan to connect the app prototype to our reservation and routing platform in order to have a truly functional application. Necessary steps include the implementation of Web-accessible service interfaces such as REST (Representational State Transfer) for making use of our custom routing algorithm and the charging station database, e.g. via AJAX (Asynchronous JavaScript and XML) calls from the mobile application. Finally, we plan to distribute the application to drivers of an EV fleet and to carry out field tests to gain real-world experience with the prototype and to learn more about the acceptance of such advanced reservation mechanisms for public EV charging stations.

6. ACKNOWLEDGMENTS

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Sneaking Interaction Techniques into Electric Vehicles

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ABSTRACT
Due to the release of several electric vehicles (EV) to the car market, the number of sales is expected to increase soon. Concerning in-vehicle information systems (IVIS) of EVs, different kinds of information need to be communicated to the driver. E.g. displayed numbers for current energy consumption or the energy left in the batteries are hereby critical in terms of a potential increase of range anxiety. In order to meet the special needs of EV drivers, manufacturers will have to rethink common designs known from regular combustion engine cars to create electric vehicle information systems (EVIS). We argue, that this fact will open up the opportunity to introduce novel interaction techniques into the EV, which have been successfully developed but have not yet found their way into the automobile. As an example, we will mention the in-car interaction via freehand gestures.

Categories and Subject Descriptors
H.5.2 User Interfaces: *Input Devices and Strategies*

Keywords
Electric Vehicles, EV, Electric Vehicle Information System, EVIS, Gestural Interaction, Freehand Gestures

EVs ON THE RISE
Due to the increased environmental awareness and the need for alternative energy sources, the number of electric vehicles (EV) will increase in the near future. With the introduction of cars like the Nissan Leaf, the Ford Focus Electric or the soon to appear BMW i3, EVs become available to the public and pave the way to reach ambitious goals such as the USA being "the first country to have a million electric vehicles on the road by 2015" [7].

DRAWBACKS AND CHANCES
Concerning the interior design of EVs, manufacturers still seem to follow the paradigm of combustion engines vehicles. Until today, the chance to develop new and exciting interior design concepts has not been taken. Electric vehicle information systems (EVIS) should be carefully designed to go beyond the conventional way of showing plain numbers about the energy left in batteries, the distance to the goal or the current energy efficiency. Instead, these pieces of information need to be combined to create novel understandable interfaces, helping the driver to be confident about capabilities of his EV. This could help to overcome EV opposing phenomena such as range anxiety.

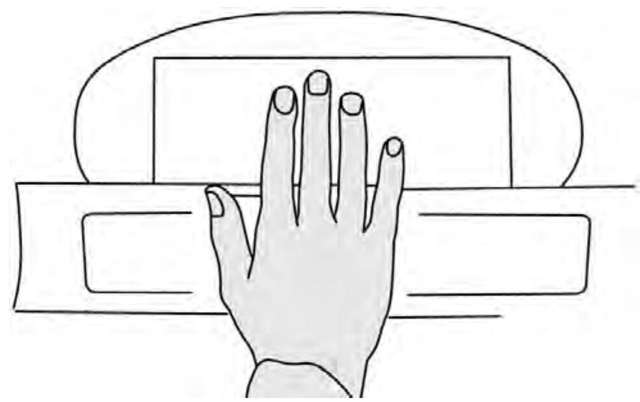

Figure 1. EVIS Interaction using Freehand Gestures

To enhance novel EVIS, and due to the fact that EVs' early adopters are in general open for novel products, the opportunity is given to introduce newly developed interaction techniques into the EV. This could be an important step towards a better acceptance of such novel systems compared to the introduction to conventional combustion engine vehicles, where the majority of drivers may be more skeptical. The example we would like to introduce here are freehand gestures, which at first sight are not directly connected to the concept of an EV, but could sneak into the automotive context with their help.

FREEHAND GESTURES
We understand freehand gestures to be intentional movements carried out by a single hand. We differentiate between microgestures performed by the fingers and midair gestures performed by the hand. The introduction of freehand gestures to the automobile context has two advantages. First, they can be applied to reduce drivers' visual distraction [4]. And second, due to the success of the Kinect in the gaming domain, they bear the potential to enhance the user experience while interacting with EVIS. Therefore, researchers developed different concepts and technologies. Akyol et al. [1] tracked hand gestures by processing the images delivered by a camera. Riener [6] used the depth image of the Kinect sensor to track the movement of a finger in order to move a pointer on a display. Varying lighting conditions while driving, especially caused by direct sunlight, are a major problem for optical gesture tracking. Endres et al. [3] detected micro gestures executed by the driver's fingers using electric field sensing similar to the musical instrument Theremin. A problem of this approach was the difficult gesture classification, meaning that some gestures were confused with similar ones. Technology independent difficulties include the misinterpretation of unintended movements (false positives) as well as undetected but intended gestures (false negatives).

Despite these examples for gestural interaction techniques, no hand gesture interaction concept is used in the interior of today's cars. The only gestural system in the automobile context was introduced by BMW [2] and enables drivers to open the trunk by performing a foot kick gesture below the bumper. Given the success of the Microsoft Kinect in the gaming market and beyond, one of the reasons why no gestural interaction systems are introduced into the car might be the drivers' low acceptance of such novel technologies. It is thus the aim to introduce freehand gestures along with several other novel systems that disregard common implementation conventions in the car by using the effect of required adaption according to changing driving properties.

CONCLUSION

Enthusiasts [5], i.e. customers buying EVs in this early development stage, are open for novel technologies in general and are thus able to pave the way to the markets. Revolutionizing the interior design of EVs can thus offer a chance to bring new technologies into the car, which had problems to be accepted in conventional combustion engine vehicles. The introduction of in-car interaction via freehand gestures, which was started over a decade ago but has not been successful so far, is a possible candidate to test this strategy.

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COPE1 – Incorporating Coping Strategies into the Electric Vehicle Information System

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ABSTRACT
Sales of Electric vehicles (EVs) are estimated by the industry to increase in the future, as they are an important step towards more energy efficient transportation and to lower CO2 emissions. A problem is that available battery technologies for EVs limit the driving range and might cause range anxiety, and as technology stands now, this problem will be present for many years to come. As a result, it is important to re-design the electric vehicle information system (EVIS) to include tools that could easily help users overcome range anxiety issues. Design of such technology can take advantage of the experience accumulated by drivers who have already coped with this problem for many years. In this paper, we describe a coping strategy observed among some more experienced EV drivers, describe why this strategy is powerful, and demonstrate a first attempt to utilize it in design.

Author Keywords
Electric Vehicle; Electric Vehicle Information System; Coping Strategies; Sustainability; Energy; Energy Management; Range Anxiety; Interaction Design; Information Visualization.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

1. INTRODUCTION
Conventional combustion engine cars have been in traffic for quite some time by now. Problems have been solved along the way, and the user interface and information system has been gradually refined and redesigned to better suit driver and passenger needs and to incorporate new technology, infrastructure and increased security. A similar endeavor has just begun for the electrical vehicle (EV), and it is likely that the EV might look much different to the conventional car in the future. However, a problem today, is that we are using the combustion engine vehicle information system as a reference for the electric vehicle information system (EVIS).

In the EV use context, where energy is tightly coupled with range, energy awareness, or lack of it thereof, manifests itself through the phenomenon referred to as *range anxiety* [1, 3]. Range anxiety is an anxiety or fear that one may not reach a target before the battery is empty, which can occur while driving or prior to driving as the user worries about later planned trips, or indeed completion of the current trip. The main cause for this problem is that EVs 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 8 hours in normal power plugs and a minimum of about 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 a trip-planning mistake, or even make the driver become stuck if the mistake is discovered too late. While there is hope for improving battery technology in the future, current knowledge does not offer cheap manageable solutions for improving battery performance.

Figure 1. An experience EV driver demonstrate how he calculates the required energy efficiency for traveling 10 km using 1 battery bar (1,5 kWh) in a Nissan Leaf.

We address this problem by doing interaction design based on coping strategies developed among experienced drivers and reshape the EVIS to meet the need of overcoming range anxiety. In earlier work we have been trying to address range anxiety by exploring how distance-left-to-empty information could be visualized in a more accurate and intuitive way, using maps and parameters of the world [2]. However, these types of calculations are problematic, as they tend to require knowledge about the future. Therefore, we are now researching alternative ways of dealing with range anxiety.

We will first describe the coping strategy we encountered with experienced drivers. This strategy is complex to apply with current EV interfaces and requires calculation on non-vehicle devices such as smartphones, and input data and results must be transferred manually between the device and the EVIS. Integrating this strategy in an EVIS is therefore a natural choice, so we will illustrate our current interaction design sketches that are based on this strategy.

2. Observations of a Coping Strategy

When conducting a one day field study meeting 2 experienced EV drivers, we encountered a range-anxiety-coping strategy that appeared efficient to us, although yet relatively simple to perform. With "more experienced" we mean EV drivers that have at least a few months experience of electric driving. One of them had driven EV for more than 5 years driving a 1998 Toyota RAV4. The other for a few years through contacts, as he was a board member of the Swedish national EV interest group, he had also owned an Nissan Leaf for 3 months at the time. Both of them could be regarded as pioneers of EV owning and driving practice in Sweden.

The coping strategy can be described by the following vignette. The experienced EV driver was going to drop off the researcher at the airport and then drive home again. First, he looked up the distance back and forth to the airport (total distance). Secondly, he checked how many "bars" he had left in his Nissan Leaf user interface (Figure 1), each of those is worth 1.5kWh and there is a total of 12 (+2 hidden ones that provide sufficient security, as known by Nissan Leaf expert drivers [4]), which means he could approximately calculate how much energy he got in the battery. Thirdly, he used his smartphone to do the following calculation:

[energy in battery(kWh)] / [total distance (km)] = [required energy efficiency (kWh/km)]

Lastly, he reset the "Energy Economy" (also kWh/km) figure in the existing Nissan Leaf "EVIS". After this, he was ready to drive to the airport. In this particular case, he had calculated that he needed to drive with an energy efficiency of a maximum of 0.15kWh/km to be able to do the trip safely. When we arrived at the airport, he had 39km home and the cars own distance-left-to-empty estimation (often called the guess-o-meter) signaled 43km. This would normally be a typical cause for range anxiety, and the first author definitely felt embarrassed about luring the driver into this disastrous situation. However, when we talked about this fact and range anxiety, he quickly replied,

"as long as I stick to the 0.15 (kWh/km) I will make it…don't worry about it".

In this situation, we believe that this strategy really demonstrated its potential in terms of easing range anxiety. It is also notable, that the strategy somewhat looks beyond the complexity of the world as in elevation, wind, number of passengers and so on, as the user always can continuously adjust the driving in relation to the required efficiency. In this sense, the strategy becomes a proactive and continuous tool, rather than a guess about how far one could reach (as the distance-left-to-empty meter) or our earlier work [2].

However, to be able to execute such a strategy, the user needs to know a few things about the EV and the world.

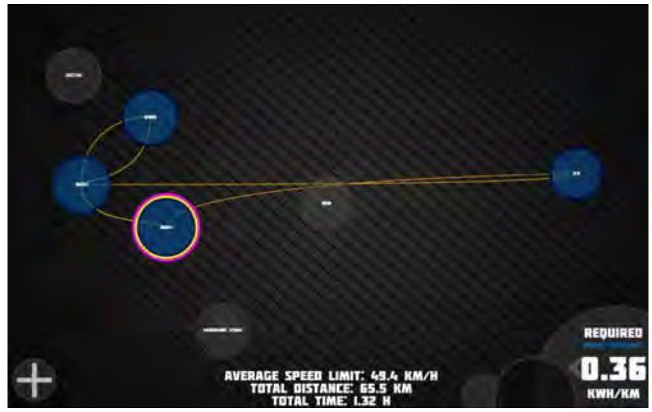

Figure 2. COPE1. The circles represent locations, blue locations have been selected in a sequence connected with the yellow to purple lines. Users can add new locations by pressing the plus sign in the lower left corner. Required energy efficiency can be viewed in the lower right corner.

1. Know about the strategy in the first place.
2. How long is the desired route?
3. How much energy do I have?
4. How do I execute the calculation?
5. Where in the EVIS can I see my energy efficiency for comparison?

All of which, could be easily supported by the EVIS to support both new and experienced EV drivers.

3. Design rationale

Based on our observation, we decided to design a prototype to begin to explore how this coping strategy could utilized in design and to further explore the values of such a strategy in the EVIS. We also assume the following to help set a direction of the design:

a) People have a limited set of locations relevant for driving and they have a good understanding of where they are. Therefore exhaustive map solution like our EVERT system [2] and many others are not relevant for everyday driving (yet they are still important for driving in unknown areas, where range anxiety is more prone to occur)

b) Users do not want to spend time on planning for everyday driving; therefore this type of tools should be effortless. Users are not prepared to do the kinds of calculations (and transfer of their results) that our EV enthusiasts performed.

c) The planning can be done both in-car or on an external device connected to the EVIS. This builds on our previous experience that "by the time you're in the car, it may be too late". The coping strategy illustrated provides a good way to adapt to the situation even as late as when sitting in the car, however taking advantage of it outside the car should do no harm but only add to the "range safety" felt by the driver.

4. COPE1 – A Coping Strategy Prototype

Our prototype COPE1 (Figure 2) is implemented using HTML5 and Processing.js and runs in any browser. In its current state we have mainly ran it in a browser on our computers to try out the idea, but it is intended for use on an iPad or similar tablet devices.

The prototype provides the user with the possibility to add locations important to them using a map. We imagine that important locations might be anything from the user's home and workplace, to the supermarket and perhaps charging stations frequently used. A circular area in the design represents each location and the distribution is loosely based on the real map location. With loosely we mean that we try to put them on the right location, but if two areas intersect they will slowly move away from each other, similar to the London Underground topological maps designed by Harry Beck in 1931 [5]. This is done to avoid "hidden" locations and thereby improve accessibility and the interaction with regards to our rationale: it should be effortless and quick to set up a plan. Every time the user adds a new location, the prototype queries OpenMapQuest and stores a distance and time matrix between all locations so that the prototype quickly can determine the length and approximate time required to travel between the locations.

When the user has added some locations it is possible to tap on a location to set a starting point that will be highlighted purple. When a starting point is set, the size of the other locations are updated in relation to the distance between the starting point and each location, in other words, the further away, the smaller location. This is done to provide some feedback on the distances and thereby also a hint on the amount of energy required to reach them.

After the starting point is set, the user can begin to form a route by adding a sequence of locations. The end location will be highlighted yellow and the route will be connected with a line. The line connecting the locations will gradually shift in color from purple (start) to yellow (end) to provide some feedback on directions. If the user wants to drive back and forth between to locations these lines will be separated so that the user have a clear visual of all fare-stages.

In the lower right corner the prototype displays the energy efficiency required to complete the whole route based on the amount of energy in the battery of the EV and the total distance of the selected route. In its current state of the prototype, the EV is always fully charged, however, latter this will be updated with the actual state of charge of the EV.

All in all, setting up a route can be done in seconds, even more complex routes, and the system automatically computes the distance and required efficiency for the route.

4.1 Current work

We are currently investigating the placement of a moving object (the car) on the topological map. This has a flexible location, so that it needs to be located at a position related to the other locations. In other words, it needs to be close to nearby locations, yet not overlap them. When this is done, the starting point will be automatically set based on the location of the EV. This also requires that the sizes (representing the distance) of the locations need to be updated as the EV moves.

Another challenge we are currently addressing is the lowest energy efficiency that is actually manageable theoretically, taking into account the factors that affect energy efficiency and are not depending on distance, such as heating and lighting. Also we are considering the lowest energy efficiency manageable practically, i.e. a low energy efficiency might require that the user drive unacceptably slow, which may also be illegal on some roads.

5. Discussion

The range anxiety coping strategy that we are considering in this paper shows an important potential in that the driver can get a measure to continuously adapt to and in some sense gain control over the EV range. This is a great advantage in relation to other forms of range anxiety help, that often tries to estimate a guess of the range without providing something to relate to in driving in terms of how much energy could be spent per kilometer [2].

However, the calculated required energy efficiency do not in itself provide feedback and comparison to what energy efficiency is actually manageable in the real world, where traffic jams, hills and cold conditions truly exists. Therefore, without such comparison, this coping strategy might fool the driver into an attempt of driving a distance with an energy efficiency that is below what is required to move a specific mass to a specific location using required features of the EV (i.e. A/C), in other words, practically impossible. We are currently looking into that problem and how to provide such feedback to the driver.

6. Future work

We intend to complete our prototype and test it with real users in real life to evaluate the value of such tools in the EVIS. Furthermore, we are planning to investigate more coping strategies to inform future designs.

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HMI Design for shared-use electric vehicles in Singapore

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ABSTRACT
The trend of sharing vehicles is on the rise in western cultures [1] and what today seems to be an attractive business case might become a necessity in the future [2].

With focus on Singapore, the rising total cost of ownership and the high and steadily increasing traffic volume make individual transport more and more expensive, inaccessible and unattractive for the majority of the people [3].

Developing vehicles with the purpose of being shared by different people from different cultures and of different social status requires us to focus on the individual demands of the potential user to reach a maximum in comfort, usability and safety. These specific boundary conditions challenge us to investigate the development of a shared, electric-vehicle information system (EVIS) application under the consideration of a heterogenic, multicultural user-group within the target market of the tropical megacity of Singapore.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces – Graphical user interfaces (GUI)

Keywords
Electric vehicle information system, design, shared-use, hmi

INTRODUCTION
The combination of innovative electric vehicle (EV) and information technologies and new strategies of vehicle utilisation gives us the impulse not only to rethink today's vehicle architecture but also the interaction between vehicle, driver, passenger and environment. The integration of new functions and the renunciation of the conventional internal combustion engine generate new types of information that have to be transferred in a precise and unambiguous way, not only for reasons of comfort but also for safety issues. To examine user behavior and customer perception of a shared vehicle interface we set up a research agenda that includes several studies with potential car sharing users. The first study is based on a time tracking survey that aims at clustering people in Singapore according to their mobility behavior. Potential car sharing users shall be detected. In a second step we will set up a focus groups to confront test persons with different car sharing models, linked technologies and different vehicle concepts. Based on these studies we expect to detect barriers towards sharing a vehicle due to social or cultural diversities (as an example for the ethnic diversity in Singapore in figure 1) and/or the denegation of certain sharing applications due to their complexity.

We acknowledge this challenges that are especially related to the changing market of e-mobility and we thus describe in this paper the framing conditions for our research to investigate the manifold barriers of adoption.

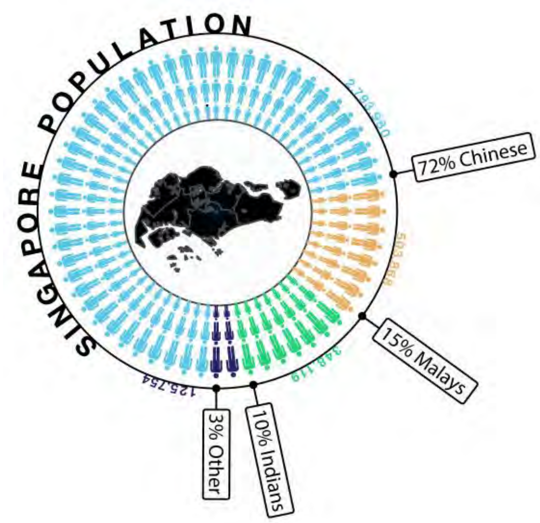

Figure 1. Ethnic Population Distribution - Singapore [4]

EV INDUCED CHANGES
The implementation of electric vehicles into the existing infrastructure requires the set-up of a new infrastructure for charging or swapping. This new environment comprises an inevitable confrontation with new technologies and especially the situation of sharing a car instead of owning, will force the drivers to adapt their confirmed habits to new circumstances. The visual, haptic and acoustic interaction between vehicle, driver and infrastructure has to be reconsidered (e.g. the indication of the range or state of charge will different from to the indication of the fuel gauge) based on the new demands of the potential target group. This is not only to make exchanged information intelligible to all but also to establish standards according to the development of new technologies and transportation models.

The strategic, intelligent and user-oriented development of these cutting points can contribute to make shared-mobility an attractive option for individual transport for a broad, multicultural user group. Detecting diversities in the user behaviour of the potential customers with the expectation to make conclusions about their demands is a challenge and shall be identified through user behaviour analysis. With focus on Singapore, the impact of the diversity of cultures, the social and demographic situation and the individual mobility behaviour is analysed.

CHALLENGES FOR A SHARED-USE EVIS

In the course of our research, questions aroused that were manifold and related to the heterogenic background of the target group: How are vehicle related symbols, signs, signals and colours for different situations and conditions perceived acoustical, visual and haptic by people of different cultural backgrounds?

Based on earlier conducted qualitative interviews we experienced that there might also be the possibility of a certain denegation of users against sharing objects with people of different cultures. These barriers for shared-using can be various, but it need to be examined what these barriers are and how they could be lowered by an optimized design/universal design. An example for these cultural differences is that in some cultures the left hand reflects the “unclean hand”. As Singapore’s traffic is based on left-hand driving, the human-vehicle interaction is mainly performed with the left hand. It is thus essential to know how the operability of an in-vehicle touchscreen in an left-hand driving vehicle look like when a right-hand driver has to operate it with his left hand.

The following research questions will thus guide our approach:

- Are there differences in the personal affiliation of people from different cultures towards certain forms, shapes, colours or brands?

- Do these cultural factors influence the acceptance of shared objects? And if so, is it possible to set up design guidelines for shared-use objects to maximise their acceptance and their operability?

- Does the visual design surface of a vehicle interface influence the driving safety? E.g. is the time of focusing, perceiving and interacting with electric vehicle interfaces interfering with the time required for focusing on the road and traffic?

CONCLUSION

In this paper we described the outlining framework for our research that we conduct to examine the implementation requirements for a shared-use EVIS.

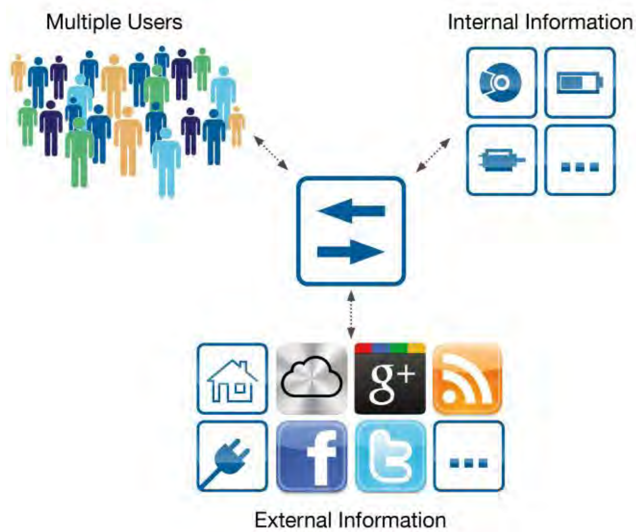

Figure 2. Flow of Information

From our point of view shared-use vehicle will gain their space in the automobile market why cultural aspects need to be considered when developing EVs for a strongly heterogenic market. As in some countries sharing is not common due to social and cultural barrier, we see the potential through user-oriented, universal product design of shared-user interfaces to improve the overall acceptance.

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Adjunct Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '12), October 17–19, 2012, Portsmouth, NH, USA

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AutomotiveUI 2012

4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications

in-cooperation with ACM SIGCHI

October 17—19, 2012
Portsmouth, New Hampshire, US

Workshop „The Social Car (socially-inspired C2X interaction)“

Workshop Organizers:

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Anind K. Dey	Carnegie Mellon University

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Preface

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Message from the Workshop Organizers

Introduction

Welcome to our workshop, "The Social Car: Socially-inspired C2X Interaction" at the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2012). 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, 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.

Summary of Contributions

The position papers submitted to the workshop of "The Social Car" have undergone a rigorous peer-review process where the manuscripts were reviewed by more than two reviewers each. Finally, eight papers (out of 11 submissions) were accepted for the publication in the adjunct workshop proceedings, all of them received at least one review with highest ranking ("Clear Accept"). Authors of selected papers were invited for participation in the workshop (presentation and discussion of their approach), held on October 17th, 2012 in the frame of AutomotiveUI 2012.

Some papers contain more **macro-level perspectives about social car**. Mario's paper 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. The design challenges met in that process could be addressed by asking and reflecting more fundamental questions such as driver's identity, elements of in-vehicle communication, and characteristics of new communities, rather than by changing user interfaces rapidly. Diewald et al.'s paper discusses "MobiliNet", which seems to be an integrated transportation service platform. They envision broader networking services including drivers, parking spaces, shopping, carpooling, public transportation, and even an electric vehicle and its charging network. It provides a blueprint of how overall vehicle-area-network services could be arranged in a single platform. In a similar line, Applin and Fischer propose "PolySocial Reality", a conceptual model of the global network environment among drivers, passengers, pedestrians, and locations. To that end, they begin to examine historical aspects of the use of in-vehicle technologies and taxonomy of the current in-vehicle technology use. Then, they discuss how software agents could enhance more robust communications in such a multiplexed situation.

A series of papers discuss **intra-car collaborations**. Perterer and Sundström conceptualize driving as a social activity or collaboration between a driver and a passenger. To facilitate the collaboration, they propose ""ACDAS" (Advanced Collaborative Driver Assistance Systems) by extending ADAS (Advanced Driver Assistance Systems). Ratan's paper also describes in-vehicle agent, but explores different types of drivers' perception about their car: avatar (as an extension of the self) vs. robot (as social entity or a partner). This paper provides not only such good taxonomy but also sounding hypotheses and questions to be discussed further at the workshop. Son and Park show empirical research on individidual differences (age and gender) in acceptance and effectiveness of the intelligent warning system. It could be an interesting discussion on whether there are similar age or gender differences regarding other vehicle-to-vehicle services in addition to ADAS.

Two papers emphasize more on how to **practically design social car services**, especially involving users in the iterative design process. Jeon provided young drivers' needs analysis about plausible vehicle-area-network services based on vivid qualitative descriptions. Tan and Colleagues introduce a "Jumping Notes" application that could be used in traffic jam. To devise this service, they employed various contextual design methods such as critical incident method, story board, and participatory design. These papers would remind researchers of the importance of overall design processes and methodologies matter in a new service design, not just technology.

Conclusion

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 initial 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 Jeon
Andrea Gaggioli
Anind K. Dey

Workshop Organizers

Andreas Riener

is a postdoctoral research fellow at the Institute of Pervasive Computing at the University of Linz (Austria). He has more than 50 refereed publications in the broader field of (implicit) human-computer interaction and context-aware computing. His core competence and current research focus is driver vital state recognition from embedded sensors, multimodal sensor and actuator systems, context-sensitive data processing/context-aware computing and implicit interaction influencing the driver-vehicle interaction loop.

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.

Andrea Gaggioli

is currently researcher at the Department of Psychology at Università Cattolica del Sacro Cuore od Milan, Italy. For over 10 years, Andrea Gaggioli has been focusing on the intersection between psychology, neuroscience and emerging technologies. This effort has lead to the foundation of a new research area – Positive Technology – which aims at investigating how new technologies can be used to promote mental and physical wellbeing.

Anind K. Dey

is an Associate Professor in the Human-Computer Interaction (HCI) Institute at Carnegie Mellon University. His research interests include ubiquitous computing and context-aware computing, user-interface software and technology, and end-user programming.

Workshop "The Social Car" or socially-inspired C2X interaction

"The Social Car": Workshop on Socially-Inspired C2X Interaction

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ABSTRACT

With everywhere available Internet connectivity and the success and broad penetration of social network services, this technology has 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 such as engine or powertrain control units into account. 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". To outline a 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, addressing questions such as 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.

Categories and Subject Descriptors

H.1.m [**Models and Principles**]: Miscellaneous—social vehicle relationships; K.4.2 [**Computers and Society**]: Social issues—status, norm, culture, ethics

Keywords

Automotive emotions; crowd sourcing; cultural differences; social status and norm; social vehicle relationships; socializing cars

1. EVOLUTION OF SOCIAL INTERACTION

In primitive times, social interaction between human individuals happened when sitting around the campfire or in the cave. This style of interaction kept almost unchanged until the mid of the twentieth century when first consumer electronics for the mass popped up, mainly driven by advances in telecommunication and electronic engineering. This progression was backed up by the emergence of information and communication technologies. Mainly caused by price decline, people started to use computers for private purposes at their homes. At this time, the transfer from face-to-face communication to human-computer interaction started its triumphal procession (and the HCI domain was born) [1].

First wave: Disappearing interpersonal interaction

While in former times extended families where living together on the countryside, this changed a lot with increased technological advance (actually starting with the industrial revolution in the beginning of the 19th century). After their job, people where sitting alone in their flats and over the time their social behavior and communication abilities degenerated. The situation has become particularly aggravated with broad emergence of ICT in the 20th century – human individuals spent more and more time in using the computer, watching TV, playing with video consoles, etc. In 1996 the "*Tamagotchi*" handheld digital pet was initially launched, a computer device that lets the player care for the pet as much or as little as he/she chooses. The "outcome" depends on the player's actions and playing with this device can be interpreted as a simple form of social interaction. As of 2010, over 76 million *Tamagotchis* have been sold worldwide. This number is a clear indication that humans need some kind of social interaction.

Second wave: Globalization and virtualization

With the availability of powerful backbone networks together with high penetration of personal computers, the Internet has opened a whole new world of opportunities for each and every individual user. While in the early days information gathering (*Altavista*) and shopping (*Amazon*, *eBay*) was the focus of users, people are nowadays using applications/games to escape into virtual worlds (*Second Life*) and to live there their life with whatever character they like.

These days, Internet-based virtual pastors/churches aims to serve religious needs of these people.

Third wave: Connectivity and social network services

In the first years of "connectedness" users were sharing files through the Internet (using services such as *eMule*, *eDonkey*) and chatting (often in private networks just as in student dormitories such as *ICQ*, later improved to *Skype*). With increasing and everywhere connectivity (e. g., cable networks, wireless LAN/WiFi, mobile cell phone operators, satellite based communication) and emergence of Internet-enabled mobile devices such as cell phones, PDAs, Smartphones, iPad, etc., the floor was opened for the whole new class of social services providing up-to-date information of its users on every spot of the planet. Social network services (*Xing*, *Facebook*, *Twitter*) emerged, connecting people globally based on common interests, political opinion, etc. The strengths' and broader establishment of such services was (and is) further enhanced by rural depopulation and increasing anonymity of the individual in large (Mega)cities.

2. TRANSITION TO THE SOCIALLY-INSPIRED CAR

The past few years were finally dominated by the broad emergence of wireless communication (IEEE 802.11p/WAVE) which led to Internet connectivity at reasonable cost even in the automotive domain. Nowadays almost each new car is connected to the Internet – the transition from formerly independently acting drivers and cars to connectedness with 'the rest of the planet' has taken place. These days more than 1 billion of cars are running worldwide (2009: 965 millions), which is more than the number of active users of Facebook (March 2012: 901 millions). This offers huge potential for social services in cars, but it might also be the source for additional distraction. What we discover in vehicular interfaces today is a still increasing number of sensors and actuators, more and larger displays, and –enabled by Internet availability and content stored in the *cloud*– feature-rich applications ('*Apps*') that have found their way into the car and the driver is more and more unable to cope with all this information. To counteract issues such as high mental demand, cognitive overload, performance losses, etc. the current research trend is coined by the catchwords "social intelligence", "social signal processing" – the ability of a system (or human being)) to understand social behavior and manage social signals of an interacting person. In the long tradition of human-computer (and driver-vehicle) interaction, computers have been socially ignorant – they have not accounted the for the fact that humans decisions are always socially inspired [9]. Next-generation computing and automotive interfaces needs to include the essence of social intelligence to become more effective and safe [9]. Therefore it is to be questioned why not should the 'car' relieve the 'driver' by taking over some tasks and accomplish them as efficiently as the human driver by application of social intelligence.

The workshop of "social cars" aims at discussing the potential of cars' socializing one with the other (similar to how humans are exchanging information), and not just translating the Internet of things (IoT) paradigm into the car domain. With the introduction of the concept of "social cars" we attempt to make a blueprint of next generation in-vehicle technologies. This is different from what the Internet of things (IoT) community is talking about in the sense that IoT is sufficient if it has its own ID that could be passively identifiable, whereas social cars have more autonomous capability, so they could serve as a more active and even interactive social being.

We are interested in a "social service beyond Facebook & Co." that creates value for the information provider. Up to now, Facebook users provide status information, social status (feelings), and much more (photos, etc.) to all the users in their network; but they do not get benefit out of it – what is the worth of yet another "friend" in the network (which you have never met or talked to before) or another "I like it!" to a written comment?

Further on, we are not only interested in social interaction between drivers (e. g., using Facebook on the Smartphone/in-car display while driving [5]), but rather focusing on the automotive domain as one field with huge potential on enabling social interactions. As like for humans, it would be relatively easy for a car to provide status information all the time (location, speed, driving destination) using all the on-board information systems, navigation device, GPS information, etc. For example, the National Highway Traffic Safety Administration (NHTSA) in the U.S. is launching a real-world test involving nearly 3,000 cars, trucks, and buses using volunteer drivers in Ann Arbor, Michigan this summer [7]. The vehicles will be equipped to continuously communicate over wireless networks, exchanging information on location, direction and speed 10 times a second with other similarly equipped cars within about 1,000 feet. A computer analyzes the information and issues danger warnings to drivers, often before they can see the other vehicle.

Furthermore, it would be possible for the car to exchange sort of social information (e. g., feelings and emotions) by taking information from diagnostics systems such as engine control unit (ECU) or powertrain control module (PCM) into account (error codes, condition of engine, clutch, etc). (Last but not least could also the mental/social state of the driver be determined and used for car status adaptations). Some issues to consider are:

- A car's social status update might be used for other, friendly, i. e., cars in same vicinity, same route or destination, similar driving (=driver) behavior, etc., cars to receive information such as a speed warning on icy road ahead, reroute recommendation on traffic jam or blocked route, etc. or to ease car sharing concepts or car pooling service (same route).
- A social car would require a social environment (intelligent roads with dynamically changing lanes; road signs adapting to the driver, etc.); one step further: social cars are not feeling well on the absence of other social cars (similar to human individuals; they cannot survive in isolation without other humans)
- Capabilities of social cars: (i) "**learning**", e. g., a jam every workday in the same region and at the same time can be learned → the car would recommend an alternative route (in particular relevant for drivers using a rental car in an unknown area) and (ii) "**remembering**", road sign with certain speed limit + cold temperature outside (i. e., ice on the road) → even when adhering to the speed limit it is most likely that an accident would

occur while cruising through a sharp turn; this fact should be remembered for the next winter (cross linkage to "learning"?: → next time in this situation: further slow down in order to drive safe) ("Route Buddy", "Sensory Bubble" concepts [5], [6]); (iii) "**forgetting**", (consider the same situation as before) in case an accident happened, forget about that incident after some time (e. g., after the winter has passed); this social behavior should avoid a car to be fearful and drive too slow in summer times (dry tarmac, temperature $> 0^oC$).
- Speed-safety curve, i. e., slowing down to 0 km/h does not increase safety to 100%. Quite the contrary is the case for example on motorways: driving too slowly increases crash risk significantly.
- "Smart road concept": Dynamic reconfiguration of the road network, for example, by changing lanes per direction inbound/outbound depending on time of day or road usage.
- "Smart signs concept": changes the maximum allowed speed based on the context; reduces maximum speed on approaching novice driver or increases the same when a professional driver is in close-by; a "overtaking denied" message is popping up on a detected lorry or jam etc. in the curve ahead, "overtaking permitted" can be shown even on poor visibility if the sign detects no other car in that area ("Intelligent Traffic Guide" concept [5], [6])

3. WORKSHOP 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 the concept of socializing cars and the topic addressed by the workshop 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.

3.1 Workshop objectives and topics

Researchers have recently started to think about the topic of socially inspired cars (the "social car") and this is actually reflected also in the AutomotiveUI 2012 conference' paper track: More than 10% of accepted papers are about social/connected cars and the importance of the topic is further strengthened be the fact that a own session will be dedicated to it. In our comprehension, a broader discussion on the benefit, consequences, etc. of socializing cars is very likely to start in the next time. Potential topics to be discussed at the workshop include, but are not limited to

- Social norm in the automotive domain
- Relevant parameters to identify/describe social status or behavior of a car (incorporate the driver?)
- Modeling techniques for handling social interaction behavior, e. g., traffic superorganism, pheromones, stigmergic behavior [8]
- Benefit assessment: why should cars (maybe drivers) disclose their 'social status', 'social relationships'?
- Understanding the potentials of socially inspired car-car communication
- Crowdsourcing
- The subject of V2V communications (driver to driver?, passenger to passenger?, driver to passenger?, driver to agent?, or agent to agent?)
- Driving as a "collaboration" with either passengers or an agent [3]
- Implementation of agents/robots for improving V2V communications [4]
- Authentication for in-vehicle social services
- Privacy, safety, or security issues related to in-vehicle social services
- Plausible types of information in in-vehicle social services
- Cultural differences in in-vehicle social services [5]
- V2V communications as a personal broadcasting station (or system)
- Other than V2V, including V2I (vehicle to infrastructure using roadside units) or V2B (vehicle to broadband cloud (network)) [2]
- Optimal protocols for social cars (WiFi/802.11p, Bluetooth, Wimax, NFC, etc.)?

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Social Activities In the Car: An Ethnographic Study of Driver-Passenger Pairs as Inspirations for Future "ACDAS"

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ABSTRACT

Driving a car can be a very social activity – especially when a passenger actively takes part in navigation tasks or operates the infotainment system. Most available Advanced Driver Assistance Systems (ADAS) fail to make use of the social nature and the collaborative mechanisms of driving. This paper explores some of the collaborative dimensions of driving, in order to inform the design of automotive user interface that helps passengers in assisting the driver. It presents how we conducted a participatory, ethnographic study with nine driver-passenger pairs recruited from an online car-sharing portal. We describe selected findings we see most relevant to the AUI community: collaborative usage of navigation devices and the speedometer as a trigger for collaboration. We introduce the acronym ACDAS – Advanced Collaborative Driver Assistance Systems – as a new term for systems, which support collaborative activities inside the car. We argue why, in our designs of future ACDAS, we need to develop a deeper understanding of collaboration in general, in addition to understanding how and in what way other platforms, such as the mobile phone, will be used in combination with automotive user interfaces. The notion of a "social car" was provided by the workshop organizers as cars social entities "socializing one with the other (similar to how humans are exchanging information)". We see the car also as a social place, where people are interacting with each other - either while they are sitting together in a car (e.g., the driver, and his/her passengers in the front- and rear-seat of the car) as well drivers wanting to communicate with their social peers via Facebook and other social services. We will discuss our findings in this position paper. The collaboration within the car allows us to investigate the car as a social and collaborative place.

Categories and Subject Descriptors

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Keywords

Driver assistance; in-car technologies; GPS; speedometer

1. INTRODUCTION

Most modern cars are now equipped with Advanced Driver Assistance Systems (ADAS). A car is a ubiquitous computing mobility device that allows for information access, communication, media consumption, and entertainment. Thus, the main goal of all ADAS – as the name suggests - is to support the driver with his primary task. However, these systems in themselves also hold a risk of distracting drivers. High complexity and demanding functionality of the ADAS hold as much risk in distracting the driver. For example, 37% of all traffic accidents are associated with inattention due to drivers' engagement in tertiary tasks, such as mobile phone conversations [6]. Therefore, the design and development of future ADAS is a highly relevant topic to the automotive community; one solution is to make them more collaborative and socially sensitive.

Driver assistance existed long before ADAS made their way into the car. Front-seat passengers do not just support the driver in finding the way to a destination, but also in handling the radio, opening snacks, as well as supporting potential backseat passengers and many other tasks. Compared to assistance technologies, assistance through a human passenger is conceptually different. On one hand, ADAS have advantages over human assistance in preventing accidents (e.g., automated braking to reduce the risk of a collision) or in maneuvering skills (e.g. keeping a safe distance from the vehicle in front). On the other hand, human assistance is superior to technological assistance systems because humans are more flexible and capable of adapting to a range of conditions. Humans can react to contextual changes during a journey in a more subtle ways and adapt their assistance according both to environmental and social factors.

Furthermore, driving has historically been a social activity. Even the first cars were not designed only for the driver. As drivers, we are often not alone in the car, a especially not when going for longer drives where we are unfamiliar with the route and, therefore, make more use of supportive systems such as the GPS [5]. In these situations, it is not uncommon that front-seat passengers help with e.g., reading and handling these assistance systems. It can clearly be stated that the front-seat passenger has a very specific role in the car. He is the second closest person to the driver's seat, which means he almost has the same access to many of these advanced systems in the car. Most ADAS are, nevertheless, neither designed for this kind of collaborative usage or for being used by front-seat passengers alone. Current ADAS greatly fail to make use of the collaborative aspects of driving.

Within this paper, we also introduce the acronym ACDAS – Advanced Collaborative Driver Assistance Systems – as a new term for systems which support collaborative activities inside the car. It differs from current ADAS (Advanced Driver Assistance Systems) which supports the driver in the driving process (e.g., lane departure warning system or adaptive cruise control). Contrary, we define ACDAS as a system which permits collaborative activities between driver, front-seat passengers or other passengers. The aim of such systems is to support the co-driver in a way that he is able to assist the driver in a collaborative way and to let him get back into his *loop* (i.e., be able to have full concentration on the driving task).

In order to develop a deeper understanding of human assistance and collaborative activities in cars, we conducted a two-month participatory, ethnographic study of nine driver-passenger-pairs recruited through an online car-sharing community from February to March 2011 [16]. In this paper, we present specific findings for the collaboration between driver and passenger, concentrating on two of the most prominent technologies in modern cars, the GPS system and the speedometer.

2. BACKGROUND

This chapter discusses the scientific foundations on which we base our investigation of social and collaborative behavior within the automotive context. It also gives a short overview of ethnographic fieldwork in the automotive domain.

2.1 Social Assistance and Collaboration in the Car

Forefront approaches [e.g., 12] in the field of technical automation deal with the advantages of human behavior in relation to the performance of machines. Thus, it has become important to understand which kind of tasks should be operated by humans and which tasks could be automated and handled by machines [e.g., 21]. Wandke [21] proposes to define assistance as access to machine functions and provides a taxonomy based on action stages to be assisted. These stages are: (1) motivation, activation and goal setting (2) perception (3) information integration or generating situation awareness (4) decision-making or action selection (5) action execution, and (6) processing feedback of action results. Such social assistance episodes are triggered by contextual cues [8]. A contextual cue signals to a person that an action or event may occur. An example within the car context is in how the front-seat passenger experiences the traffic situation as dangerous and assumes that the driver is not able to solve the problem without assistance. Then it could be, that the front-seat passenger supports the driver by, for example, operating the navigation system. In such situations, collaboration between drivers and front-seat passengers is of high relevance as highlighted by Forlizzi and colleagues [7]. Their results indicate the importance of accessibility and flexibility of information based on the intervention of front-seat passenger assistance. What we propose in this paper is not just assistance but more of collaborative usage of these systems.

2.2 Ethnographic Approaches in the Automotive Domain

There have been several ethnographic studies investigating the relationship between the city and the car [19], the family and the car [20], and the pleasures of listening to music in the car [3]. Studies such as [1,4,5,11,14] encourage the benefits of studying interior related aspects with an ethnographic approach. One example is the ethnographic study conducted in 2007 by Esbjörnson and colleagues that focused on the usage of mobile phones in vehicles [5]. Oskar Juhlin and colleagues [4] take a broader engagement on driving and design and has designed a series of games and systems for the social experiences of driving (e.g., pervasive games). Their fieldwork underlines the ways in which driving is a process whereby road users “solve coordination problems with other road users and try to influence each other” [11, p.49]. The use of GPS was discussed in [1,15]. Leshed and colleagues [15] present an ethnographically informed study with GPS users, showing evidence for practices of disengagement as well as new opportunities for engagement. Brown and Laurier [1] identify five types of troubles where GPS systems cause issues and confusion for drivers. Bubb [2] emphasizes that it may be helpful for developing future ADAS to learn more about human assistance during real driving conditions. Our paper argues how in order to design future ADAS, we need to go back to the routes and nature of human assistance.

3. STUDY

Our study took place from January to March, 2011. Nine driver-passenger pairs were recruited from an online car-sharing community. We looked for routes at the car-sharing platform that started and ended in our vicinity. Based on the information of the car-sharing platform, we called participants that regularly drove those routes with other passengers. Participants were aged between 20 and 32 years (27,9 in average); 7 male and 2 female drivers. The nature of the car-sharing community enabled us to observe collaboration on various topics and between people with different relationships. Four of the nine driver-passenger pairs met each other through the community. Two of them were either friends or students fellow. The rest of them (three) had a solid relationship.

To investigate human assistance, a researcher joined participants by sitting in in the backseat. The researcher observed and conversed with the driver-passenger pair. Paper and pencil was used to log situations. Although we acknowledge the advantages of technical support such as video, we wanted to observe real-interaction without additional technical artifacts. Thus, the researcher gets more involved and has no social distance to participants. Technical devices could cause artificial behavior of the driver-passenger pair and could also distract the driver. In addition, we wanted the trips to be as natural as possible without delaying departure by installing any equipment. We wished to use the car-sharing platform as unobtrusive as possible.

All drivers were registered on the car-sharing website. One of them tested a car-sharing platform for the first time. The participants drove different cars such as Audi A3, BMW1, Peugeot 207, Volkswagen Polo, or Mercedes Vito. Four out of nine drivers used a mobile navigation device. In one specific case the driver had a laptop mounted on the center stack with Google Earth running.

4. RESULTS

The observed episodes collected in our study were analyzed using an interaction analysis approach [9]. Two researchers classified each observation into three categories: highway assistance (127 assistance episodes), assistance on rural roads (28 assistance episodes), and assistance on urban streets (41 assistance episodes). They clustered the noted assistance episodes and actions for comparison in terms of similarities. The recorded material represented patterns of behavior, triggers, and context factors that influenced the human assistance and level of collaboration while driving. Finally, we reflected on the results and triangulated them to confirm ideas. This resulted in four categories: types of front-seat passenger assistance, user experience related to human assistance, context factors and triggers for supporting the driver, and different forms of communication which require a mutual understanding of knowledge between the driver-passenger pairs.

In this paper, we present selected topics: (1) collaborative usage of navigation devices and how those systems sometimes are aided by a second device (2) and the speedometer as a trigger for collaboration. In the next two chapters, we present two particular ethnographic episodes in detail. The first highlights collaborative navigation activity between one driver-passenger pair. The second describes how a specific front-seat passenger was curious about driving information such as the current speed.

4.1 Collaborative Usage of Navigation Devices

In the first episode we want to mention Mr. A (the driver) and Mr. B (the front-seat passenger), who were driving back from a meeting at night. They met through the car-sharing community and were now friends. As soon as they entered the highway, it suddenly began to snow.

Mr. A (the driver) switched on the radio to hear the traffic news. The radio voice then said: “There are heavy snowfalls in the South of Bavaria, which have caused traffic jams. Many motor trucks are getting stuck in the snow.” After hearing this, Mr. A (the driver) decided to take another route because he was afraid of being stranded in a traffic jam for half the night. He immediately left the highway and explained to Mr. B: “We should avoid highways. It might be a good idea to drive on rural roads.” On this account, Mr. B did not fellow the instructions provided by his navigation device. For that account, Mr. B entered an alternative route. At increasingly short intervals Mr. A (the driver) monitored the screen in order to estimate the arrival time. He seemed to be exhausted. Mr. B noticed his behavior and asked him if he needed any assistance: Is everything ok? You look tired. Should we change seats? At the beginning, Mr. A (the driver) answered: No. No problem. I have just followed the instruction from the navigation system. And now, I do not know, where we are and how far away we are from the main route. After a while, Mr. B suggested that he could use the “Navigon” application that he had installed on his smartphone in combination with the navigation unit: “You are looking at the road instructions, and I am looking on the map to clarify where we are.” Mr. A answered: “Good idea! When you have found where we are, you can give me instructions. In the meantime I will look at my navigation system.” Mr. B took his smartphone out from his trouser pocket and started the “Navigon” application on his mobile device. From that moment on the driver-passenger pair used two systems simultaneously (see Figure 1).

As our data shows, collaborative navigation is a common activity for driver-passenger pairs. Drivers and front-seat passengers are often working together when the driver has problems to understand the output of the navigation unit or GPS signal is lost. In those situations, both passengers and drivers interact with the navigation system to interpret and resume routing. Especially, during night Mr. A (the driver) needed more assistance from Mr. B to find where they were and how far away they were from the main route.

4.2 The Speedometer as a Trigger for Collaboration

In the second episode, we present Mr. C (the driver). He had been registered on the car-sharing platform for two years. Today Ms. D (the front-seat passenger), a fellow colleague of Mr. C (the driver), was riding with him. They were in urban traffic, which is mostly regulated between 40 and 50 kilometers per hour. Mr. C (the driver) drove ten percent faster than allowed. Ms. D was sitting on her seat, just watching a film on her mobile phone.

At first, Ms. D did not intervene at all. She said nothing, but did not avert her eyes from looking at the speedometer. Mr. C (the driver) exceeded the speed limit by more than ten percent. Ms. D turned her head for a moment to the driver`s side to see the current speed. Later Ms. D intervened and explained to Mr. C (the driver) “Don`t forget to look at the speedometer. I get the impression you are driving to fast. We should not risk getting a ticket.” Later the driver-passenger pair was approaching an intersection, suddenly Ms. D stopped watching the clip on YouTube and said: “You are driving to fast. Slow down, there could be traffic lights, which have integrated speed controls.”

Special attention was given when approaching traffic lights with integrated speed controls. If there were many vehicles waiting at a red traffic light, a front-seat passenger (see Ms. D) stopped her task (e.g., watching a video) and complained about the manner of driving. If the traffic light was orange or green, Ms. D stayed quiet and said nothing.

5. DISCUSSION

Drawing from our findings, there are some suggestions we can give concerning the design of future ACDAS. Our aim with this study is to provide inspiration to design of new ACDAS with contextual and traffic-related information for driver-passenger pairs. It might be interesting for the AUI community to reflect about possible implications for the design of human-human mediated, socially sensitive and collaborative systems. Based on our two described episodes, we could identify the three following themes which can serve as a base for designing new ACDAS; *Collaborative navigation, Control,* and *Adapted Assistance.*

5.1 Collaborative Navigation

As we all know, navigation tasks sometimes demand more assistance from the front-seat passenger by e.g., monitoring the driver’s route selection or helping him interpret or resume the instructions given by the device. Our ethnographic study reveals that collaborative navigation is an important feature. In the described episodes we have presented here, it is noticeable how in particular in darkness a current ADAS, which is providing turn-by-turn instructions based on GPS-satellites, is not always sufficient for navigation (see figure 1). In terms of satellite-based GPS systems Brown and Laurier [1] have already mentioned that the situated instructions are not “simply” instructions but are puzzle pieces that must be assembled by the driver or someone helping him. During night trips through unfamiliar areas the driver seemed overloaded with the information presented on the display, and needed more help from the front-seat passenger (see episode one).

In our findings, we could also see how driver-passenger pairs (Mr. A and Mr. B) made use of additional equipment. For instance, the driver used the portable unit (mounted on the center stack) for detailed information, whereas the front-seat passenger simultaneously aided him using his smartphone that then provided them with an overview picture.

In this context, we argue that future ACDAS should be designed for the needs and behaviors of both drivers and front-seat passengers. We state that navigation systems could also be oriented towards also the front-seat passenger, who then could initiate a complex search task and support the driver. Future ACDAS should be designed in a way that they open up for and support coordination and collaborative activities.

Figure 1. The front-seat passenger and the driver are navigating with different devices trough unfamiliar areas

Our aim with this work was also to point out the benefits that can be achieved from a deeper understanding of the collaborative in car activities that already take place around these systems. As inspiration for example the work by Nomura and colleagues [17] shows how experienced teams are able to accomplish complex navigation tasks faster, and with less errors than individuals.

One can then argue how current ADAS already are used this way as we can see both in the second described episode, but also in the data provided by Brown and Laurier [1]. Our argument, however, is how it also needs to be an explicit aim when designing these systems. Future ADAS should be designed in a way that they open up for and also support these coordination and collaborative activities. This should help to get drivers into the loop of collaborating when there is a front-seat passenger and the situation requires it.

5.2 Control

Although appearing very particular, the second episode of our research shows that a front-seat passenger also likes to share the basic information about the car (i.e., current speed). In terms of displays in the dashboard, this means that also the front-seat passengers wants to be informed about the current speed level of the car. Of course, we admit that ADAS in some cases have advantages over human assistance in preventing accidents (e.g., automated breaking to reduce speed). As researchers and designers we should keep in mind that to give away the total control of the driving task by (semi-) autonomous systems is always a matter of trust [18], for the driver and additionally for all passengers. Therefore, making passengers more aware of the driving performance and the car data in general is not just a matter of front-seat passenger assistance, but also a matter of comfort for the passengers. Additionally, our research confirms the need for a separate passenger interface, especially for navigation purposes. Since passengers are not busy with driving, they can for example use maps with a higher interactivity and information density.

We argue not to provide only basic information about the car to the front-seat passenger but also specific situation based information. This gives the driver the opportunity to use the front-seat passenger as a reminder. We state that future ACDAS should not be designed to encourage passenger intervention more than the driver appreciates. A fundamental question that arises in this context is: Should the front-seat passenger be in the position to intervene in any circumstances?

5.3 Adapted Assistance

We also observed how passengers often adapted their assistance, which is not underpinned with a described episode, depending on the stress level and current state of the driver. As stated before, passengers could potentially keep track of the more detailed information in stressful situations while the driver could then be freed from information that is not directly connected to the primary task of driving the car. While people who are friends/colleagues know each other, this is not always the case for all driver-passenger pairs. Some passengers might miss how the driver would need assistance. Or it might be annoying for some drivers when a passenger knows that the driver is in a bad state and gives unwanted assistance. We envision a system that keeps the front-seat passenger and the driver updated about the current traffic situation and perhaps also the state of the driver. This would allow the passenger to adjust assistance.

According to Wandke [21], knowledge of human assistance could be used to guide design of future ADAS to allow for more adapted behavior. Our ethnographic study provides knowledge of the establishing phase in human collaboration, in which the passenger approaches the driver and somehow tests how the mental state of the driver is. Based on the driver`s reaction, the passenger judges how to communicate with him and what kind of assistance to give.

Interactive technology should employ some of the same processes and adapt its behavior based on the driver's reaction. Changes observed in human communication for example include interrupted or delayed communication patterns, which is something future ADAS for a single-entity potentially also could incorporate and then perhaps adapt the length of information units.

Summarizing, we can see how a deeper understanding of human collaboration and assistance while driving is a great resource in the development of future more collaborative in-car assistance systems, called ACDAS.

6. CONCLUSION

The front seat passenger interaction space is not sufficiently covered in current vehicle interface solutions. With our two described episode of our ethnographic fieldwork, we draw attention to findings that can be used to inform future automobile collaborative approaches. An interface that will be designed according to the needs and behavior of both the driver and the front-seat passenger could establish a common ground. This will let them coordinate activities together and will help to get the driver into the loop of collaborating with the front-seat passenger. Navigation systems and speedometers for instance could be also oriented towards the front-seat passenger, who then could initiate a complex search task and make it easier for the driver. We see how a deeper understanding of human collaboration in the car can be a fundamental part in the development of future in car assistance systems.

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Exploring Car-to-Car Communication in Traffic Jam: Contextual Design and Practice

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ABSTRACT
In this position paper, we describe our research and design practice in car-to-car social communication. As a part of larger research project, we investigate the drivers' action, needs, and requirements in traffic jam. By contextual design and other integrated methods such as critical incident method, story board, and participatory design, a concept proposal of car-to-car communication in traffic jam "Jumping Notes" has been designed to solve the problem of information access of the jam. The proposal has been adopted by Nokia Research Center.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces–*Theory and methods, User-centered design*

General Terms
Human Factors

Keywords
Car-to-car communication, contextual design, traffic jam, participatory design

1. INTRODUCTION
Nowadays, more and more cars can access Internet and the future car will be used as no more than just a transport but a social communication space. While driving, the main focus of drivers is to maneuver the car and increase its safety [4]. Therefore, we need to find an appropriate chance and context to help drivers to communicate with other cars. In this paper, we introduce our approach on studying the drivers in the traffic jam to find the chance and the following concept design. The approach is a part of a larger scale project "Development of Transportation User Interface Design Knowledge System", which aimed to establish a knowledge system for help to design automobile user interface on the basis of the ethnographic study and contextual design.

2. METHODOLOGY AND APPROACH
2.1 Methods
In the study, we adopted the "contextual design" as the basic structure of the study and integrated the valuable ethnographic methodologies and other user-centered design methods related to these field research methodologies. The integration of these methodologies can provide the comprehensive understanding of drivers' contexts and create breakthrough ideas/concepts.

The study consisted of two types of methods: exploring methods in filed study and innovation methods in design.

The main exploring method in contextual design is contextual inquiry, a qualitative field study technique used to capture detailed information about how users of a product interact with it in their location [3]. On the basis of the contextual inquiry, an interview after the drive was also important for obtaining deeper understandings of the task in traffic jam and the drivers' requirements. The traditional ethnographical method "critical incident method (CIM)" was used as the supplement of contextual inquiry. CIM is an interview and observation method for investigating critical significance [2]. In the interview, we asked the participants about the events with significance. In addition, other ethnographic methods such as photo diary, story board were used in the exploring approach. After collecting the data, a coding scheme was developed based on the qualitative coding rules of Strauss et al. [5] and Tan, et al. [6]. This coding scheme separately identifies the category of the design factors (e.g., navigation (NAV), traffic jam (JAM)) and their type (e.g., the concerns (C), processes (P), design implications (DI), and product suggestions (PS)). Using this coding scheme, the original conversation and notes can be transformed to design issues, from which insights and ideas would emerge.

In the innovation stage, we involved users with designers and engineers following the methods of participatory design. Participatory design is an approach to design attempting to actively involve stakeholders (e.g., end users) in the design process. Participatory design could help to ensure that the designed product meets their needs and is usable [1]. In the study, users participated in the design process, and one of our designers used paper prototype to visualize the users "design" and discuss it with them. After the participatory design, storyboard and paper prototype were the main visualization methods. In addition, some detailed methods such as mockups and videos were used in the design stage.

2.2 Approach
The qualitative field study and contextual design were conducted from 2011 to 2012. We recruited 104 Chinese participants aged between 20 and 54 years from seven typical Chinese cities based on the region, city size, industrial and economic conditions. Figure 1 shows the contextual inquiry in the field. After the field study, 102 of the participants took part in the following workshop and participatory design and innovated with designers and engineers.

Figure 1. Contextual inquiry in one participant's car.

3. RESULTS

The study generated 497 ideas in 6 categories: macro-driving activity (such as going home, traveling), micro-driving scenario (such as traffic jam, highway driving), supporting driving (such as ACC), information consuming (such as accessing internet, communication), entertaining (such as listening to music/radio), and others (such as traffic accident). In these ideas, 69 of them were related to traffic jam and we chose one idea and finish a concept design: Jumping Notes.

Jumping Notes was one of the proposals in the study. In the approach of Jumping Notes, we identified one issue in the "traffic jam" scenario: "*The drivers wanted to know the reasons caused the traffic*" from 29 participants' conversation, such as "*I feel sad for I cannot know what happened. If I can talk with the drivers in front of me, I can know it.*" From this conversation, we produced one idea: a communication system in the jam using NFC in car. We drew a storyboard to describe the use case of the concept (See Figure 2).

Figure 2. Story board of "Jumping Notes".

Based on the story board, we designed the concept: Jumping Notes (Figure 3). Jumping Notes was a small application in central controlling display. The driver can write his/her message on a virtual note in the centered display in car and send it to the front drivers by the NFC in car. The message can deliver in the jam site and build up a temporary social network within the jammed drivers. The drivers can share their information and communicate with each other by the "notes". Figure 4 shows the usage flow of "Jumping Notes".

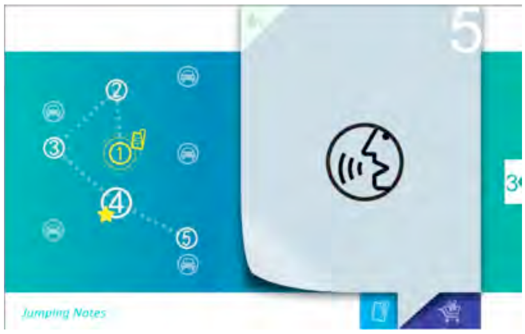

Figure 3. The "Notes Delivery" Screen in "Jumping Notes", designed by XY Wang, D Xie, et al.

As a design concept, Jumping Notes provides a possible solution to communicate within drivers in traffic jam by using NFC. Meanwhile, there are also other possible patterns to communicate in such scenario. For example, the information also can be directly transferred to each driver by a traffic information system. All these concepts should be tested in real scenarios and evaluate the effect of them. Currently, Jumping Notes presented with prototype in Chinese version only, which have been adopted by Nokia Research Center (Beijing) and is applying the patent now.

4. CONCLUSION AND FUTURE WORK

Traffic jam is an appropriate context for car-to-car social communication. In the study, we proposed the concept solution "Traffic Jam" in such context.

Social communication in car is a very important topic and exploring the automotive UI design is the main work for the possible chance towards future. We will continue to the innovation design on the basis of the research findings and find the actual opportunities in practice.

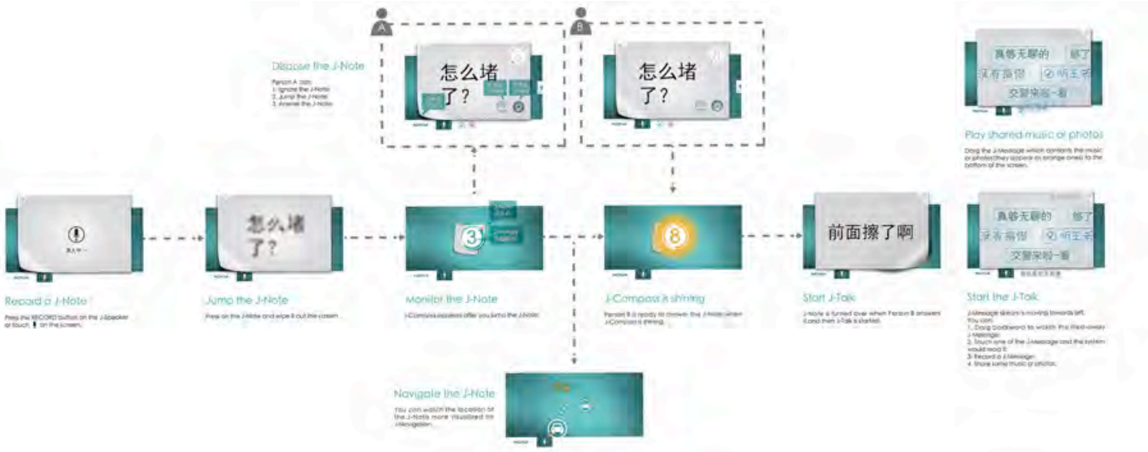

Figure 4. The Usage flow of "Jumping Notes".

5. ACKNOWLEDGMENTS

This work was performed in the project 60903090 supported by National Natural Science Foundation of China and the project 11JJB002 supported by Hunan Provincial Natural Science Foundation of China.

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Age and Gender Differences in the Acceptance and Effectiveness of Intelligent Warning Systems

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ABSTRACT
Objective: This paper aims to investigate age and gender differences in the acceptance and effectiveness of intelligent warning systems. **Backgrounds:** Understanding of age and gender differences in technology acceptance and effectiveness towards intelligent in-vehicle services may help successful introduction of new technology in auto-market. **Method:** 52 drivers were participated in on-road field experiments. With or without ADAS (Advanced Driver Assistance Systems) support, they drove approximately 7.9km on urban road (about 25 minutes) and 36km of highway (about 20 minutes). After completing the driving experiment, the ADAS-supported group (a half of all participant) responded to questionnaire. **Result:** The results suggested that age and gender differences in the effectiveness and acceptance of intelligent warning system were significant, and the effectiveness and acceptance can differ from its intended effects.

Categories and Subject Descriptors
J.4 [Social and Behavioral Sciences]

General Terms
Human Factors

Keywords
Intelligent Vehicle, Technology Acceptance, Age and Gender Difference, Forward Collision Warning, Lane Departure Warning

1. INTRODUCTION
In order to meet consumers' desire to extend their connected lifestyle, automakers provide drivers with intelligent driver assistance systems and services. However, technology acceptance and effectiveness may vary by gender and age groups. According to the American Automobile Manufacturers Association, drivers age 60 and older are the principal purchasers of 23 percent of new passenger cars in the United States [1]. Since many older drivers purchase new vehicles, understanding of age difference in technology acceptance and effectiveness towards enhanced safety systems and connected car services may offer an opportunity for the older drivers' vehicles to incorporate technologies that may help them compensate for some of their diminished driving capabilities. There are a variety of advanced driver assistance systems such as electronic stability control, brake assist, forward collision warning systems, lane departure warning systems, adaptive cruise control, and night vision, are available in market. ADAS can compensate for driver distraction risks caused by advanced connected infotainment systems [2]. According to the Highway Loss Data Institute (HLDI), forward collision avoidance systems show the biggest crash reductions and lane departure warning (LDW) appears to hurt, rather than help [3]. The opposite of LDW's intended effect can be caused by driver's lower acceptance due to some reasons such as frequent false alarms and unpleasant warning sound. Therefore, acceptance of new technology is vital for implementation success. This leads to a number of research efforts on in-vehicle technology acceptance.

A standardized checklist for the assessment of acceptance of new in-vehicle technology was proposed by Van der Laan to compare impact of new devices with other systems [4]. Regan et al. [5] stated that usefulness, ease of use, effectiveness, affordability and social acceptance are the key components for technology acceptance. Comte et al. [6] studied driver acceptance of automatic speed limiters to discover how acceptable drivers considered a speed-limiting device to be. Piao et al. [7] assessed acceptance of ADAS and automated vehicle guidance (AVG) using operator and user surveys. Brookhuis et al. [8] assessed mental workload of drivers and acceptance of the system to understand the effects of driving with a congestion assistant system on drivers. However, there has been little research has been conducted on age and gender difference in effectiveness and acceptance of forward collision warning and lane departure warning systems.

In this study, the impact of intelligent warning systems on driving behavior related to safe driving was investigated through on-road experiments and the participants' acceptance of the intelligent warning systems was surveyed. The findings suggested that age and gender differences in the effectiveness of intelligent warning system were significant, but the acceptance was not significant.

2. METHOD

2.1 Subject
For this study, 52 younger and late middle age (LMA) drivers were participated (see details in Table 1) and they met the following criteria: age between 25-35 or between 55-65, drive on average more than twice a week, be in self-reported good health.

Table.1 Participants overview

	Younger		Late Middle Age	
Gender	Male	Female	Male	Female
# Subject	13	13	13	13
Age*	27.54 (2.90)	30.46 (3.10)	60.69 (1.89)	57.08 (2.06)
# ADAS	7	6	6	7

* Note. Means with standard deviations

2.2 Experimental setup

The experiments were conducted in a full size sedan that is instrumented for collecting time-synchronized data. The DGIST instrumented vehicle consists of six video cameras (two for a driver and four for road environment monitoring), high speed and low speed CAN logger, lane position and headway recorder, driver gaze tracking system, and physiological measurement system. The DGIST-designed custom monitoring software was separately running on four windows-based PCs and synchronized by storing the measurement data with master time that was sent by a main control PC.

2.3 Intelligent warning system

An aftermarket ADAS (Advanced Driver Assistance System), Mobileye C2-170 (Mobileye, Amstelveen, The Netherlands) was used to provide forward collision warning and lane departure warning features [9]. The forward collision warning application monitored the roadway in front of the host vehicle and warned the driver in situations where the host vehicle is approaching a preceding vehicle with a high closing rate, and the lane departure warning application monitored the position of the host vehicle within a roadway lane and warned a driver if the vehicle deviates or is about to deviate outside the lane.

2.4 Questionnaire

26 Participants (7 young males, 6 young females, 6 late middle age males, and 7 late middle age females), who were supported by forward collision and lane departure warnings during their experiments, were given a questionnaire covering perceived safety, preference, inconvenience and annoyance while using the forward collision warning and the lane departure warning. Among the four components perceived safety and preference indicate positive responses, and inconvenience and annoyance are negative. Each question used 1-to-7 rating scale.

2.5 Procedure

Following informed consent and completion of a pre-experimental questionnaire about safe driving (safety protocol), participants received about 20 minutes of urban and rural road driving experience and adaptation time on the instrumented vehicle. The main driving experiment began when a subject was confident in safe driving with the instrumented vehicle. In a main experiment session, participants drove in good weather through 5.5km of rural road (about 10 minutes), 7.9km of urban road (about 25 minutes) and 36km of highway (about 20 minutes). The rural road has speed limit of 70kph and one lane in each way; the urban road has speed limit of 60kph and two to four lanes in each way, and the highway has speed limit of 100kph and two lanes in each way. After completing the driving experiment, the only ADAS-supported group (a half of all participants) filled in questionnaire.

2.6 Dependent Variables for Evaluating Effectiveness of ADAS

For analyzing effectiveness of forward collision warning, average velocity (AV) and headway (AHDW) were considered. For the lane departure warning, standard deviation of lane position (SDLP) and steering wheel reversal rate (SRR) were used.

2.7 Data Analysis

Statistical comparisons of the effectiveness measures were computed using SPSS version 17. Comparisons were made using a general linear model (GLM) procedure. A Greenhouse-Geisser correction was applied for models that violated the assumption of sphericity. For the acceptance questionnaire measures, comparisons were made using Kruskal-Wallis test.

3. RESULTS

3.1 Age and Gender Differences in Attitude Towards ADAS

According to Technology Acceptance Model (TAM), computer-related technology acceptance behavior are influenced by perceived usefulness and perceived easy of use [10]. Among the four attitudinal questions including perceived safety, preference, inconvenience and annoyance, safety may be related to the usefulness because the main purpose of these intelligent warning systems is to improve safety. The term of ease of use is related to inconvenience and annoyance in the questions of this study, because the only use case of the warning systems is to accept the warning or not. Thus, technology acceptance will be increased as perceived safety goes higher and annoyance (or inconvenience) is lower.

As shown in Table 2, younger female group showed the most negative responses to both forward collision warning and lane departure warning systems. That is, the lowest values in safety and preference (positive attitude) and the highest values in inconvenience and annoyance (negative attitude) were appeared in younger female group. The most positive opinions in the forward collision warning were appeared in younger male group, and late middle age male had the most positive attitude towards the lane departure warning. Based on the Technology Acceptance Model based assumptions, male drivers are likely to accept to use the intelligent warning system than female groups, and younger female drivers may not accept the warning systems.

Table.2 Results of attitudinal questions

Forward Collision Warning				
Questions	Younger		Late Middle Age	
	Male	Female	Male	Female
Safety	6.00 (1.00)	4.83 (1.47)	5.50 (1.87)	4.86 (1.21)
Preference	5.71 (0.95)	4.17 (1.17)	4.83 (2.04)	4.71 (1.80)
Inconvenience	3.00 (1.41)	4.17 (0.75)	3.00 (2.10)	3.71 (1.38)
Annoyance*	2.29 (0.95)	3.67 (1.51)	1.67 (0.52)	3.00 (1.41)
Lane Departure Warning				
Questions	Younger		Late Middle Age	
	Male	Female	Male	Female
Safety	5.29 (1.89)	4.83 (1.17)	5.67 (0.82)	5.14 (1.21)
Preference	4.71 (2.06)	4.50 (1.38)	5.67 (0.52)	5.57 (1.81)
Inconvenience	3.43 (1.90)	4.83 (0.75)	3.33 (1.37)	3.43 (1.40)
Annoyance*	3.29 (1.70)	4.17 (1.17)	1.83 (0.41)	3.29 (1.60)

* $p < 0.05$

3.2 Effectiveness of ADAS Warning

In order to evaluate the effectiveness of ADAS warning, four driving behavior measures, i.e., average velocity and average headway for forward driving performance and standard deviation of lane position and steering wheel reversal rate (SRR) for lateral driving performance, were selected. (For the details on SRR calculation, see [11].) The results were compared under two different environmental conditions including highway and urban driving.

3.2.1 Highway Driving

As shown in Figure 1, the ADAS-supported younger drivers significantly reduced their average velocity on highway (F(1,148)=9.926, p=0.002). The average headway in all groups was significantly impacted by FCW (F(1,148)=4.484 , p =0.036). Especially, the ADAS-supported male drivers increased their headway by 8.9m (16.3%) (F(1,148)=9.099, p=0.003). This result suggested that FCW was effective for male drivers to improve driving safety on highway.

However, the lane departure warning systems slightly decreased lateral control performance on highway, i.e. SDLP and SRR was increased in general (see Figure 2), but the effect was not significant. It means the effectiveness of LDW seems to be limited in normal situation of highway driving.

3.2.2 Urban Driving

Figure 3 and Figure 4 demonstrate the effect of FWC and LDW respectively. Contrary to highway, urban driving situation was more complicated and disrupted by environmental factors such as traffic signal, parked cars, traffic density and pedestrians. Thus, the effect of FCW was not significant, but LDW significantly impacted on SRR (F(1,304)=7.322, p=0.007). The ADAS-supported group had higher steering reversal activities by 14.2% than non-supported group. SDLP of the ADAS-supported younger male was also significantly increased (F(1,304)=17.528, p=0.000). It means that the participants had higher effort to keep their lane when LDW was activated. Thus, the effectiveness of LDW is hard to determine as positive because the increased lane keeping effort can produce higher mental workload.

4. DISCUSSION

This study provides general understanding of the acceptance and the effectiveness of intelligent warning systems through on-road field study. For the acceptance, younger female group showed the lowest acceptance, and younger and late middle age male groups were more likely to accept the systems. In age difference, the late middle age groups' preference of LDW was higher than that of younger groups. This may be rooted in the older driver's diminished driving performance especially lateral control ability [12-13]. Son et al. reported that the older Korean participants drove with more variability in lane discipline [12]. Thus, the late middle age groups may have more interests and preference to the device to compensate their degraded ability.

For the effectiveness perspective, FCW significantly impacted on headway safety margin and younger driver's velocity on highway driving, but no significance in headway and velocity on urban road. The results suggested that FCW could be a useful device to enhance highway safety. However, LDW seemed to slightly decrease lateral control performance on highway and significantly increased SRR on urban driving. The results that coincided with HLDI report [3] raised a question whether LDW can indeed enhance driver's safety.

In summary, the results demonstrated that age and gender differences in acceptance and effectiveness of in-vehicle technologies were existed. However, the results slightly differ from the general expectation. That is, LDW showed the opposite effectiveness of its intention, and younger female showed the lowest acceptance. The results suggested that it is essential to assess age and gender differences in effectiveness and acceptance

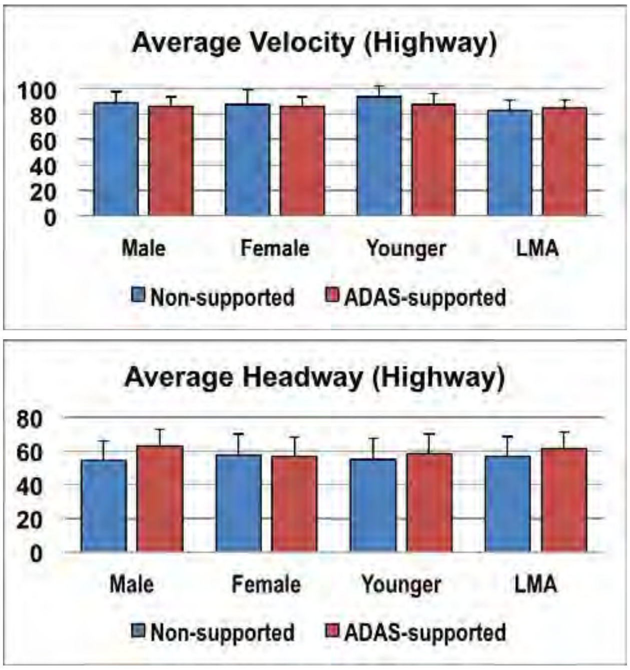

Figure 1. Comparison of Velocity and Headway between FCW-supported and non-supported groups on Highway

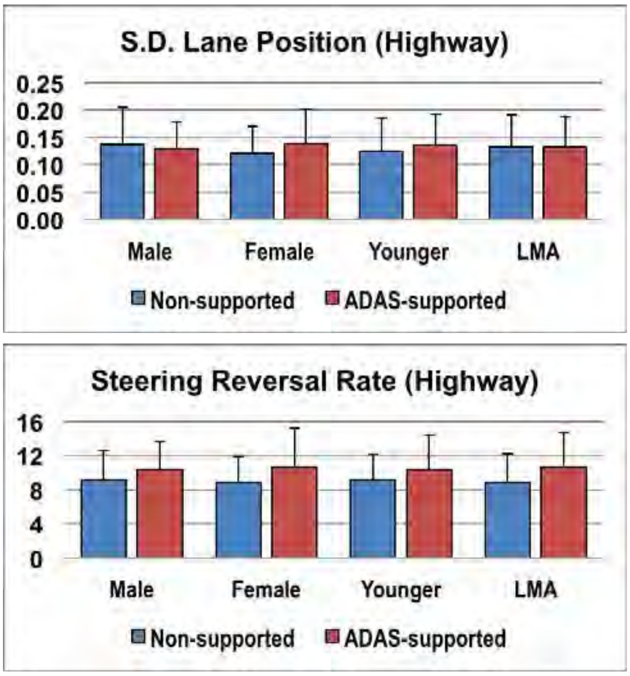

Figure 2. Comparison of SDLP and SRR between LDW-supported and non-supported groups on Highway

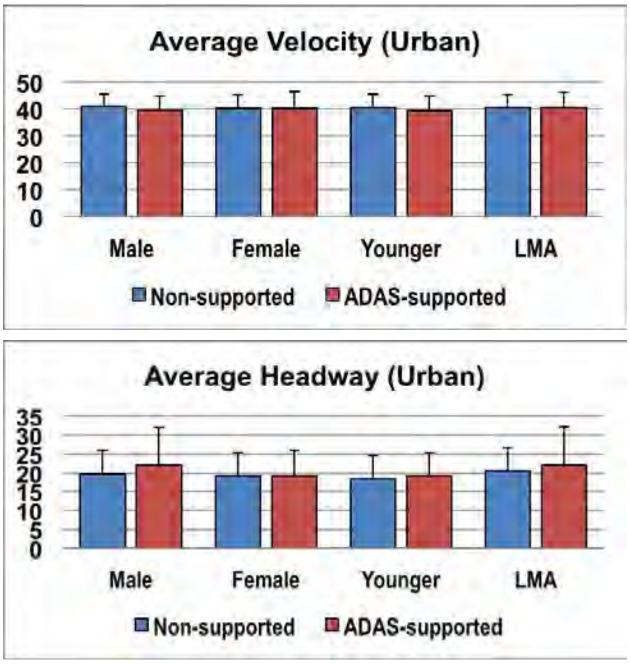

Figure 3. Comparison of Velocity and Headway between FCW-supported and non-supported groups on Urban Road

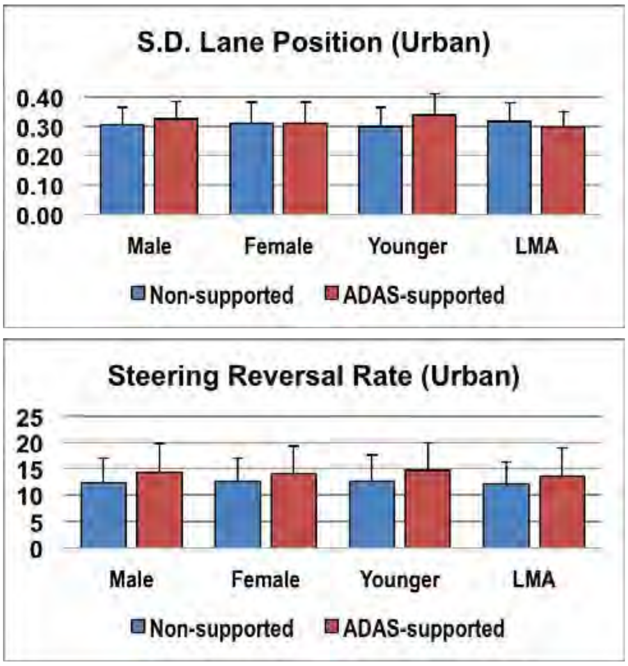

Figure 4. Comparison of SDLP and SRR between LDW-supported and non-supported groups on Urban Road

of new in-vehicle technology for avoiding unexpected negative effects on a certain age and gender segment.

5. ACKNOWLEDGMENTS

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MobiliNet: A Social Network for Optimized Mobility

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ABSTRACT

In this paper, we present our vision of *MobiliNet*. *MobiliNet* is a user-oriented approach for optimising mobility chains with the goal of providing innovative mobility across different types of mobility providers – from personal short range battery powered mobility aids over different types of public transports (e.g. buses, short distance train networks) to personal mobility means (e.g. car sharing).

Our vision for *MobiliNet* is based on a social network-like system that is not limited to human participants. By including vehicles, corporations, parking spaces and other objects and spaces, the system could make traveling more comfortable and less stressful, and finally more efficient for the travellers.

MobiliNet allows high-level trip planning, but also pays attention to other important details of the supported means of transportation. Especially for user groups with special needs, *MobiliNet* actively supports self-determined mobility. Thus enables again an active participation of this user group in in social life. Besides supporting travellers, the system could also create new business opportunities for transport associations and car sharing corporations.

Keywords

Intermodality, mobile device, mobility chains, self-determined mobility, social networks, social transportation network, vehcile-to-x communication.

1. INTRODUCTION

Seamless mobility, provided by intermodal mobility chains, is a great challenge, especially in rural contexts. We understand intermodality as follows, though focusing only on human transportation: 'Intermodality is a quality indicator of the level of integration between the different modes: more intermodality means more integration and complementarity between modes, which provides scope for a more efficient use of the transport system. The economic basis for intermodality is that transport modes which display favourable intrinsic economic and operational characteristics individually, can be integrated into a door-to-door transport chain in order to improve the overall efficiency of the transport system.'[1] Providing efficient mobility across individual means of transportation and offered by several independent mobility providers, is a challenge for personal mobility in tomorrow's networked society.

In contrast to the trend of urbanisation where especially younger people move to the growing cities, elderly people are staying in rural environments. These creates additional challenges to the mobility chains, i.e. be accessible for people with special needs such as elderly people, people with limited physical mobility (i.e. due to handicaps), people with baby carriages, etc. Barrier free accessibility according to the existing norms can address these problems only partially. Broader and holistic concepts are needed here. In rural areas, even fit people that do not need to carry anything around can have problems traveling only a few kilometres when they do not own a private car. Given that most privately owned cars are standing for more than 90% of the day and the costs of ownership and mobility, alternatives are needed that ensure personal mobility in the future. Therefore, many people are dependent on the assistance of people owning a car, or have to stick to the sparse public transportation schedules.

In order to improve the mobility situation with these users in mind, we have designed our vision of *MobiliNet*. *MobiliNet* is an user-oriented approach for optimising mobility chains for all kinds of user groups, not limited to people needing barrier-free access or other support. Our social network-like system allows for allocation and coordination of mobility services and can be accessed by all Internet-connected devices. We, by this approach, treat the network of vehicles like a social network, as it has e.g. be done with objects in the context of the Internet of Things [10]. This allows using the system from everywhere. And due to the great success of smartphones and tablet PCs, most people could even use the system while traveling. The usage of modern Internet connected devices does not automatically mean the exclusion of elderly people. For example, Kobayashi et al. have evaluated the touchscreen interaction of elderly users and created a set of guidelines for creating user interfaces that can satisfy the demands of all age groups [7]. Following rules like that, one should be able to create a system that could be operated by everybody.

MobiliNet is based on a platform which interlinks not only people with each other, but also vehicles, public transport stations, parking lots, and other mobility related systems and services. The integration of "things" into Internet-services is often referred to with the term "Internet of Things" [11]. Adapting this term to our approach, one could say that *MobiliNet* is a service for the "Internet of Mobility".

The remainder of the paper is structured as follows: We first situate our vision with respect to future visions and

[1] `ftp://ftp.cordis.europa.eu/pub/transport/docs/intermodal_freight_transport_en.pdf`, last accessed August 24, 2012.

existing systems. Then, we describe the concept behind *MobiliNet* and discuss technological possibilities for the realisation of the system. After that, a sample trip plan shall, in form of a scenario, highlight the capabilities of the system. In the conclusion, we give a summary and provide an outlook towards a working prototype we are currently working on.

2. RELATED WORK

When talking about networks of vehicles, most people are thinking of vehicle-to-x (V2X) communication and VANETs (vehicular area networks) and not of social networks, but actually both can be the case. V2X has been named the 'first social network for automobiles'[2]. Ford's concept car Evos even goes one step further: this car can directly social network with the car driver's friends[3]. Additionally, the modern car behaves' like a personal assistant that suggests routes and keeps an eye on the driver's work schedule as well as on the traffic situation and weather conditions.

There are also several social network like systems for cars that are based on mobile devices. For example, *SignalGuru* [8] uses windshield-mounted phones for detecting current traffic signal states with their cameras. By combining multiple measurements, the service creates a schedule and gives its users a so called green light optimal speed advisory (GLOSA) or suggests an alternative route that efficiently bypasses the predicted stops. Test drives have shown a potential of saving 20.3% vehicle fuel consumption on average. Another example is WAZE[4], a crowd souring approach targeted at more efficient transportation, employing also ramification to encourage participants to contribute and compare themselves against other contributors. Mobile device integration in the automotive domain is also an enabler for various services and can have multiple benefits for the driver [4]. For example, the device can be used as head unit replacement which allows using the same interface and preferences in different vehicles. This is especially an advantage for car sharing scenarios. The mobile device is becoming either a replacement for an in-vehicle information system (IVIS), or is complementing it, providing extended additional features.

Yasar et al. have developed a social ubiquitous-help-system (UHS) for vehicular networks [14]. By using friend-of-a-friend (FOAF) relations for sharing information, they ensure that only relevant and reliable information has to be shared between the nodes. The context-awareness of this approach allows improving the efficiency of a vehicular network, since data necessity, data locality and data routing can be determined before sharing the information.

Clique Trip [6] allows connecting drivers and passengers in different cars when traveling as a group to a common destination. In order to establish the feeling of connectedness, the system automatically switches to an alternative navigation system when the cars tend to loose each other. In that way, the cars are following the leading car and can find each other again. Whenever the cars are within a defined distance, the system further establishes a voice communication channel between the vehicles. In order to form such a multi-car traveling group, it is necessary that the trip is registered beforehand via a mobile device. The mobile device is further responsible for providing the information from the central *Clique Trip* server to the car's infotainment system during the travel.

[2]`http://media.daimler.com/dcmedia/0-921-881044-1-1519299-1-0-0-0-0-1-12759-614216-0-0-0-0-0-0-0.html`, last accessed August 24, 2012.

[3]`http://mashable.com/2011/09/01/evos-social-networking-car/`, last accessed August 22, 2012.

[4]`http://www.waze.com`, last accessed August 22, 2012.

3. MOBILINET – CONCEPT AND TECHNICAL REALIZATION

We named our system *MobiliNet* since we want to optimize users' individual and personal mobility by connecting each other and complement this approach by mobility-related services. For that reason, the platform supports numerous participants (stakeholders). An incomplete example selection of possible *MobiliNet* stakeholders is depicted in Figure 1. Besides the potential end users, also institutions, systems, and services can be part of the network.

In our vision, we assume that the user is accessing *MobiliNet* with a modern personal portable device, such as a smartphone or a tablet PC, that has mobile Internet access. We further assume that the user is used to so-called apps and interacting with them. The user will be employing a special *MobiliNet* client application that allows for a better integration in the mobile platform, e.g. Android.

3.1 Participants' Roles and Available Functions

The main functionality of our envisioned system is the support of the end user by providing more efficient means of personal transportation across modality borders. In order to be able to optimally assist the user, s/he has to create a profile on *MobiliNet*. By default, the profile is private, but parts of it can also be made publicly available so that friends can find each other. The profile consists of mobility preferences (cost limits, requirements, restrictions, . . .), and travel-related information. For example, the user can configure whether s/he has a driver's license, needs barrier-free access, or owns a private car that s/he is additionally potentially willing to share. Additionally, available public transport tickets and personal subscriptions can be set for calculating pricing alternatives. Other preferences, such as the preferred mode of transportation (e.g. with the private vehicle) can be used to refine the system's behavior. A central part of each user's profile is a calendar. The calendar can be synchronized with common online and desktop calendars. Users can also connect to friends and other known people. Depending on the degree of confidence, they can share their profile information as well as their calendar. The well-known means of sharing information on social networks are used to implement this feature, e.g. the circle model of 'Google+'. This feature allows, for example, creating car pools by scheduling appointments next to each other. The user utilizes *MobiliNet* to plan her/his trips. This can be done for future trips from a defined start point to a destination (for example, an appointment planned via the system), as well as for ad-hoc trips from the current location to any destination.

Organisations, authorities, and shops can also register for *MobiliNet*. They can also connect their calendar with their profile. This feature can, for instance, be a common base for scheduling appointments. The scheduling algorithm could take the user's journey into account and only offers appointments for defined slots. When trusted neighbours have an appointment nearby or even at the same place in the future, and the next appointment for the client falls in same period

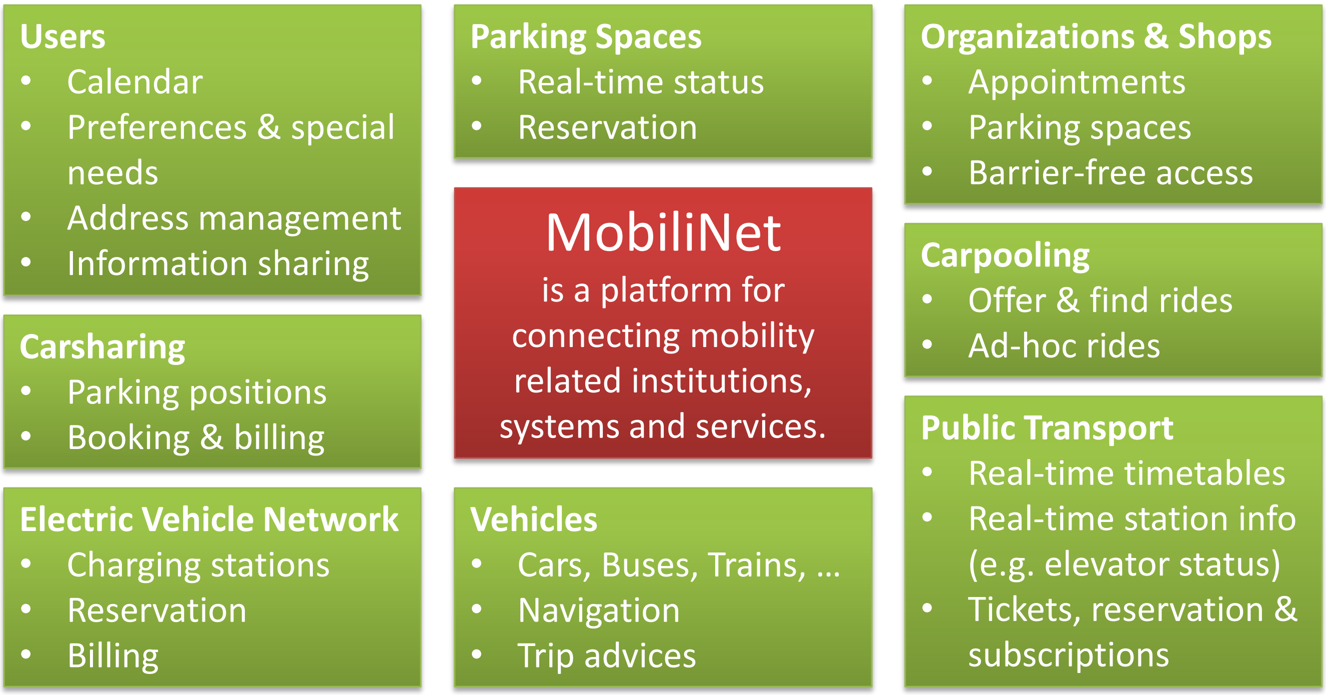

Figure 1: Overview of possible *MobiliNet* participants. Our platform should be able to connect all mobility related things.

of time, the system could offer the client an appointment so that they can create a car pool. Of course, the system would only suggest this when one of the clients plans to go there by car and is accepting car pooling for that journey. Additionally, the corporations or authorities could offer and reserve parking spaces for their clients for their next appointment. This would especially be easy when an intelligent parking solution is used.

Intelligent parking solutions could as well be directly linked with *MobiliNet*. Parking spaces can either be managed by participating organisations, or they can be available for all users. When planning a trip, the user can, for example, reserve a parking space for the desired time. Additionally, organisations can provide parking spaces for their clients. By binding the parking space reservation to the user's trip, the user's navigation application can directly lead her/him to the reserved parking space. Since the network knows about special needs of the users, it could also take care of them. People with a mobility handicap can, for example, get a nearer parking space, and people with babies or toddlers could get assigned a broader parking space so that the getting in and off would be more comfortable. When a user is traveling with an electric vehicle, the system could automatically choose a parking space with a charging station, when available and not reserved at the moment. We assume that this will be realised in connection with the politically supported introduction of e-mobility. At the 'Nationale Strategiekonferenz Elektromobilität' in November 2008 in Berlin, the German government announced a national target of 1 million Electric Vehicles by 2020[5]. The inclusion of these services is therefore a logical consequence.

[5] http://ec.europa.eu/clima/policies/transport/vehicles/docs/d1_en.pdf, last accessed August 22, 2012.

The incorporation of existing public transport options into *MobiliNet* could make journeys more comfortable and less stressful. This could not only be helpful for people without private cars or driver's licenses, but also save time and additional reduce CO_2 emissions. In cities, there is often heavy traffic, and usually, the parking situation is already at or over its limits. For that reason, it could be beneficial to park outside the inner city and to use public transport to get to the final destination in the city - if a convenient travel alternative could be provided. In order to find the optimal multimodal route, *MobiliNet* would estimate the traffic situation for the planned time of travel, e.g. by incorporating historic traffic data. When a user has to transport something (like Billy shelves from IKEA), or when she/he does not want to take public transport, *MobiliNet* would not consider public transport. For users with special needs, the public transport operator could offer real time information for elevators and other accessibility relevant systems. In that way, *MobiliNet* could also react during the trip and provide alternative routes and information to the user. Real time information could also be provided by the transport vehicles. This would allow, for example, the user to estimate whether a connection could be reached, when she/he is already late, or is going to arrive late.

Car sharing operators and car pooling initiatives/portals could also get part of the network. By providing the possibility to book or reserve cars (or at least places in cars), these mobility alternatives could get a fixed part of mobility chains. For short-term journeys, car sharing and car pooling are only attractive when reliable real-time information and binding booking is available. This information and booking functionality could be directly provided by *MobiliNet* when the user plans a route.

Participation in the *MobiliNet* network could also be interesting for electric vehicle charging station operators. They could, for example, provide a booking mechanism for their charging stations and make use of *MobiliNet*'s seamless payment possibilities for billing. Real-time information about the current price per kilowatt-hour could further be displayed directly to the user, when she/he is searching for a recharge station.

3.2 Vehicles as Part of MobiliNet

A special of *MobiliNet* is that also vehicles (conventional cars, electric bikes, or personal mobility platforms like a Segway or a Renault Twizy[6]) can participate in the social network-like service. Since the service can be accessed via all Internet-enabled devices, modern vehicles with mobile data connections can directly be linked with it. In contrast to safety critical V2X applications, standard IP connectivity with higher delays over 3G/4G would be sufficient for the system. It is also thinkable that the user's mobile device gets connected to the vehicle's infotainment system for providing the desired information from *MobiliNet*.

When a normal user account is coupled to the in-vehicle system, *MobiliNet* provides the route chosen by the user for the vehicle's navigation system. When a parking space is assigned to the user for a trip, the reservation is automatically updated with the license plate information of the utilised vehicle. This ensures that the parking space is reserved for the user, no matter what vehicle she/he is using. In addition, the system could broadcast the estimated time when a user arrives at a destination. An example scenario for this functionality could be when another user shall be picked up, she/he could check whether the car is on time, or not.

Additionally, cars can participate in *MobiliNet* without being linked to a user. In that way, they could, for example, detect and report free parking spaces [1], or report traffic data to *MobiliNet*'s central route calculation system. Electric vehicles could use the system for requesting nearby charging stations that are in range of the current battery level. Additionally, when a user plans a trip with a private electric vehicle that is assigned to his *MobiliNet* account, the current battery state reported by the car could be taken into account. That means that the system would automatically choose a parking place with charging station, or suggests to park somewhere, where the user could get back home without charging.

Public transport vehicles running at regular service could also be linked to the respective connection and time slot. This would allow broadcasting information, such as the delay or the utilisation, in real-time. This could be important information for users that are already late and want to get their connection. For people in wheelchairs, people with baby carriages, or people with large luggage, the information about the utilisation could also be critical, since often the number of places for such user groups are strongly limited. When other passengers in the transport vehicle are also part of *MobiliNet*, the system could further try to create an estimation, whether there should be enough places, or not.

The flow of information is not limited from vehicles to other participants, but also the vehicles could be provided with information. For example, when an underground train arrives late and a bus on a line that is scheduled at 30-minutes interval is part of the trip for some travellers, the bus could inform the driver about the lateness and the expected time to wait. In that way, the driver could decide whether she/he wants to wait, or not. When users in wheelchairs or with carriages want to get on a vehicle that is not barrier free by default, *MobiliNet* could also inform the driver to prepare the loading ramp, to lower the bus, or to get ready to help someone with special needs entering the vehicle.

[6] `http://en.wikipedia.org/wiki/Renault_Twizy`, last accessed August 22, 2012.

3.3 Accessing User Profile Information and Billing

For offering matching mobility services to a user, organisations and service providers would need access to some user data that is stored in her/his profile. One of the fundamental design principles of the system should be the protection of the user's privacy. Thus, only approved users and trusted services would be able to access her/his data. For that reason, the system should have a fine graded user-managed access control [2]. A sample protocol that could be used for giving access to third parties is OAuth 2.0[7]. It provides authorisations flows for web applications, desktop applications, mobile applications as well as for consumer media devices.

The linking can, for example, be realised by scanning a QR code with the *MobiliNet* running device, or via near field communication (NFC). This could trigger an access screen that shows what service wants to access what kind of data. The user could then either accept or decline the request. In that way, she/he would not have to enter her/his password in an insecure environment. The coupling could either grant an one-time access, for example, when a corporation wants to create an appointment in the client's calendar, or a not-time limited access. In the second case, the user could manage and revoke the access permission for each service at any time. The one-time access could, for instance, also be used for coupling car sharing vehicles on a per trip basis. This would allow using *MobiliNet* on the vehicle's system as long as the car is booked.

Billing is another interesting part of *MobiliNet*. Especially for people that are not used to ticket vending machines, or have difficulties in understanding network and fare plans, an active support with billing could take away the fear from public transport of these people. Since most larger public transport associations are supporting online or mobile phone ticketing, the system could directly buy the tickets when the users agrees in taking a route proposal. For systems without advanced ticketing, the public transport operators could provide step by step instructions for the most common available tickets. This step by step guide could then be displayed when the person enters the area where a ticket vending machine can be found. For car sharing operators and car pooling scenarios, it would be possible that the payments could be carried out via *MobiliNet*. The payment service could be realised by linking with immediate transfer services, online payment services, or common credit institutes.

3.4 Multimodal Route Calculation

In order to create multimodal trips, several data from different sources has to be combined. Basic routing information could, for instance, be derived from OpenStreetMap data. The OpenStreetMap (OSM) project "creates and provides free geographic data and mapping to anyone who wants it"[8]. The data already includes barrier free accessibility information for some buildings. And, since everyone can contribute

[7] `http://oauth.net/2/`, last accessed August 27, 2012.

[8] `http://wiki.openstreetmap.org/wiki/Main_Page`, last accessed September 2, 2012.

to the data, way and buildings could be added and rected by everyone. This would ensure, for instance, also parking spaces from companies could be found by system. The routing system could be based on one of open source routing implementations for OSM. For ex ple, *Gosmore* offers a full route calculations for vehicles pedestrians[9].

For public transport, the respective data sources from different transport operators and associations have to queried. The popular Android application *Öffi* is alr successfully using many existing application programi interfaces of public transport operators and demonst that this data is accessible and reliable[10]. Nevertheless, t are not yet standardized interfaces for transportation tems available that can be used in third-party impleme tions.

Besides the route and the duration under normal cc tions, the system could also use other sources for determi a more comfortable route, or for creating a better estima of a journey. For example, the system could include wea conditions when planning outside walking route parts Or, it could make use of historical floating car data (FCD predicting the traffic at on a special day, similar to TomT route planning assistant that makes use of gathered live fic information from mobile phone operators and GPS r gation systems[11]. Since the user always carries her/his sonal portable device while traveling, the algorithms c further adapt themselves in various manners. For exan the system could optimise the estimation of the user's w ing speed or her/his driving behaviour, by measuring speeds and other sensors' values.

3.5 User Tracking for Advanced Service

When a user travels with *MobiliNet*, she/he could make use of advanced services when tracking is enal Advanced services could be, for example, the notifica of traveling or appointment partners, when the user is ning late, or the on-the-fly alternative route calculation v something changes.

When traveling outside, the application could make u the device's localisation technologies. This could, for ex ple, be the GPS system or localisation via cell ID or V access points or other built-in radios of personal mobile devices, even DECT [9] or FM radio [13]. To detect and support passengers traveling with *MobiliNet*-support in public transport, the vehicles and stations could, for example, be equipped NFC service point where a user can check-in and check-out with her/his NFC-enabled mobile device, or provide a free WiFi that can only be accessed when the *MobiliNet* application is running on the device.

4. MOBILINET SCENARIO

In Figure 2, a possible route suggestion from *MobiliNet* is shown. For this scenario, a user with a private electric car wants to drive to the centre of Munich, Germany. The user does not need barrier free access or any other special support. S/he has further no public transport subscription.

At a first glance, the output looks similar to standard public transport trip planers (like Öffi). But *MobiliNet* combines multiple things: Routing for a private vehicle, parking, and planning the final part of the journey with public transportation. Additional to the route, it also displays and incorporates the electric vehicle's battery state in the trip preview. Since the battery is charged enough to get back fully electric, the system does not output a warning, but chooses a parking place that also offers recharging stations. The recharging station could further be directly reserved from the route preview.

Since the user has no subscription for the transport network, the system calculates the cheapest available fare and allows buying the ticket directly via the application. In case, a user would have planned multiple journeys within the public transportation network, *MobiliNet* could also suggest buy-

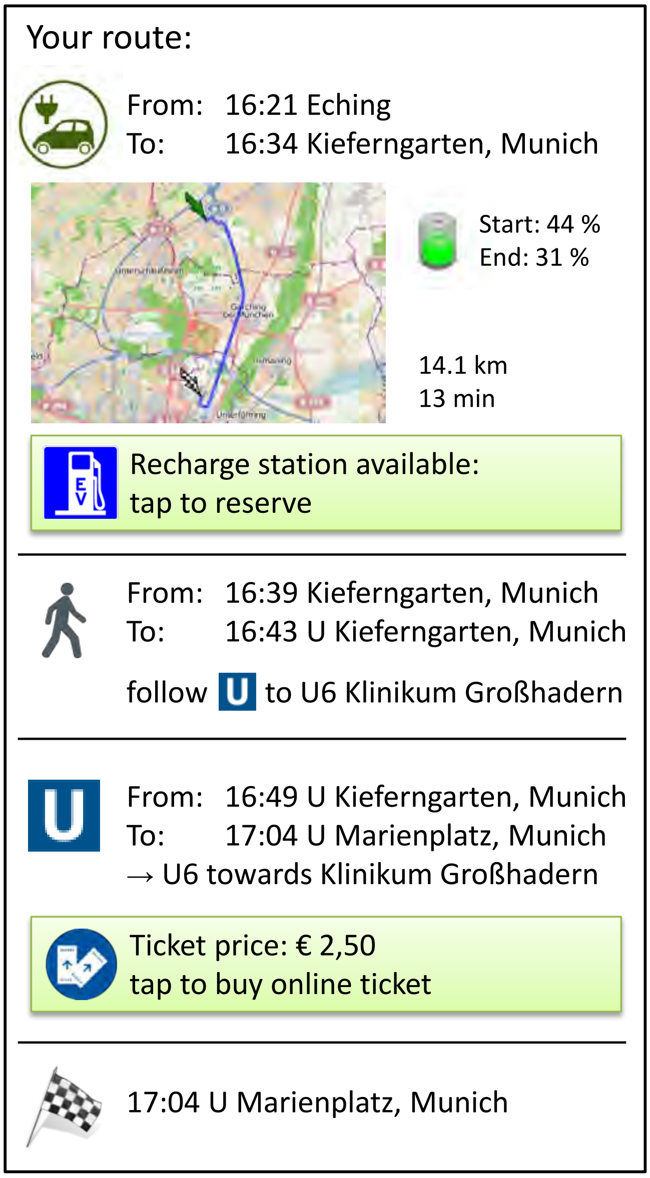

Figure 2: Our mock up shows how a possible route output of *MobiliNet* could look like. It could, for example, offer possibilities for reserving a charging station for the electric vehicle and for buying a public transport ticket. Map source: OpenStreetMap

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[9] `http://wiki.openstreetmap.org/wiki/Gosmore`, last accessed September 2, 2012.

[10] `http://oeffi.schildbach.de/participate.html`

[11] `http://routes.tomtom.com/`, last accessed September 2, 2012.

ing a day, week, or month ticket, whenever a cheaper alternative is available.

5. CONCLUSIONS

In this paper, we have introduced our vision of *MobiliNet*. Based on a social network-like system, it could optimise the mobility chains for all kind of user groups. Besides optimising the individual mobility, it contributes also to an overall more efficient mobility since it allows connecting people that are traveling to the same destination. The system does not only provide a high level trip planning, but also incorporates important details for all supported means of transportation. Since the system handles a lot of personal data, privacy and security is an important point. For that reason, we think that such a system could, for example, be run by the government financed by the participating public transportation associations and other benefiting corporations.

MobiliNet could also contribute to the optimisation of travel demand management strategies [15] since trips could be planned far ahead in most cases. This can, for example, be used to optimise public transportation systems by choosing different transportation vehicle sizes.

We have already realised some basic parts, which could contribute to the proposed system. With *DriveAssist* [5], we have created a fully working Android-powered driver-awareness system, that can combine traffic information from central traffic services and V2X communication. Our approach for integrating mobile devices with V2X communication would further allow sharing mobility related information directly between nearby vehicles [3].

In future work, we are planning to create a working prototype of the proposed vision. Our focus will be on electric vehicles as core part of private transportation combined with public transportation, and the electric vehicle charging network.

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The AVACARS Project: Examining Cars as Social Media to Improve Driver Safety

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ABSTRACT

Many drivers have close relationships with their cars as separate social entities, as well as strong feelings of identification with their cars that are enhanced through customization and other means of communicating identity through the car (e.g., bumper stickers). This dichotomy – car as social entity vs. self-extension – is the central topic of this paper. We coin the term "AVACARS" (Automotive Vehicles As Communicating Avatar-Robot Systems) to describe this dichotomous relationship and then present a set of hypotheses about how differences in the AVACARS relationship may influence driving safety. The paper describes survey and experiment-based tests for the hypotheses and then concludes that feedback from researchers and industry partners would be essential for targeting the research toward its goals.

Categories and Subject Descriptors

J.4 [**Computer Applications**]: Social and Behavioral Sciences – psychology and sociology

General Terms

Human Factors

Keywords

Avacars, social driving, driving safety

1. INTRODUCTION

Although drivers have interacted with one another since cars first entered the roadways, we are currently experiencing a transformative moment in the social nature of the automobile. The integration of the mobile internet into the driver's seat is facilitating an eruption of social media applications ("apps") that allow drivers to interact with each other in novel and meaningful ways. For example, there are numerous apps that encourage drivers to upload information (e.g., locations of traffic jams, police traps, etc.) and communicate with other drivers on the road (e.g., view profiles, send messages), and some of these apps have sizeable and growing user bases (e.g., Waze, >20 million users, www.waze.com; Trapster, >16 million users, www.trapster.com). The use of such apps while driving may seem dangerous, especially given the dangers of other types of mobile phone use while driving (e.g., texting) [1], but many people still report using their phones for such activities [2] and not all people are negatively affected by such multitasking [3]. Further, autonomous driving technologies have advanced significantly in recent years [4], suggesting that drivers in the near future will have more cognitive resources available for safely engaging in other activities while driving. The purpose of the present proposal is not to examine this intersection of mobile apps for drivers and autonomous driving technology,[1] but instead to address the idea that by integrating the technologies described above, the automobile itself can be considered a social medium with social characteristics that can influence driver safety.

2. THE DUAL ROLES OF CARS

There is a strong culture in America of drivers having close relationships and feelings of identification with their cars [5, 6]. For example, many people attribute a specific gender and personality to their cars [7], thereby treating the car like a separate social entity, such as a friend. People also select or customize their cars to communicate a unique personal identity to other drivers on the road [8-10], thereby treating the car as an extension of the self. This dichotomy – car as social entity vs. self-extension – parallels the ways in which people perceive robots, with which people communicate as a separate social entity [11], and avatars, through which people interact socially with others [12-14]. In order to emphasize this dichotomous relationship between the driver and vehicle, we have coined the term "AVACARS", or Automotive Vehicles As Communicating Avatar-Robot Systems. However, it should be noted that the two poles of the dichotomy are not necessarily mutually exclusive: some people may see their car as an avatar and a separate social entity (perhaps dependent on the social situation). This is an open research question. The hypotheses below can be used to examine this research question as well as numerous other questions about the ways in which this dichotomy is relevant to driver safety.

3. HYPOTHESES

There are many open questions regarding the ways that the concept of AVACARS can be used to improve driver safety. Our research team has drawn from a plethora of research about the influence of social factors on driving safety [15-21], as well as research about how various facets of online interaction affect people's attitudes and behaviors toward each other [12, 22-35], to

[1] The author is currently working on a separate project on this topic.

define a set of research questions and expectations. Given space constraints, the arguments supporting these expectations are not presented here, but a small sample of relevant hypotheses follows below:

- Hypothesis 1a: People who view their car more as an avatar engage in more social interactions with other drivers.
- Hypothesis 1b: People who view their car less as a separate social entity (i.e., robot) engage in more social interactions with other drivers.
- Hypothesis 2: The more a driver perceives the cars on the road to be avatars (i.e., identity extensions of others), the more this person will trust other drivers.
- Hypothesis 3: The more a driver feels socially connected to other drivers, the more likely the driver is to engage in safe driving behaviors.*
- Hypothesis 4: The less anonymous a driver feels on the road, the more likely the driver is to engage in safe driving behaviors.*
- Hypothesis 5a: Drivers who perceive their cars to be less aggressive-looking will engage in safer driving behaviors.
- Hypothesis 5b: The relationship articulated in Hypothesis 5a is stronger for people who treat their car more like an avatar.
- Hypothesis 5c: The relationship articulated in Hypothesis 5a is stronger for people who view their car less as a separate social entity (i.e., robot).

4. POTENTIAL STUDIES

The hypotheses above can be tested in a series of survey and experiment-based studies. For the former, a large, representative sample of an appropriate population of drivers would be given a survey with questions about their relationship with their cars, attitudes about other drivers, and driving safety habits (see below for examples). While self-report error and bias may detract from the fidelity of this research, this approach would be able to provide broad reaching insights into the research questions based on real driving experiences. An experimental approach would utilize a high-fidelity driving simulator and include manipulations and/or measurements (similar to survey-based study) of participants' relationship with their cars, attitudes about other drivers, and driving safety in the simulated environment. For example, participants could be primed to think of their car as either more of an avatar or a separate social entity (i.e., robot), and then they could drive in a simulated environment that includes other (real or artificial) drivers with whom the participants are encouraged to communicate while driving. ANOVA and regression analyses could be used to examine the relationship between all manipulated/measured constructs and thereby test the hypotheses.

4.1 Example Questions

These questions can be used in both potential survey-based and experimental studies. All would use Likert scale agree/disagree response options

Car as avatar

- My car's decorations (e.g., bumper stickers, fuzzy dice, etc.) represents some aspect of my personal identity
- When my car has mechanical troubles, I feel unwell in my own body.
- While driving, my car feels like an extension of my body on the road.

Car as social entity

- My car has a name
- I speak to my car out loud
- I think of my car as a friend

Social interaction with other drivers

- I often look at other drivers in the eye at intersections
- I am comfortable communicating with other drivers.
- When driving, I feel like other drivers can identify me easily
- I think of other drivers as people who could be my friends

Safe driving practices

- During past year, I received ____ tickets for speeding
- When the light turns yellow at an intersection, I usually speed up to get through it.

5. OUTLOOK

This project aims to contribute to academic knowledge as well as improved safety through the informed development of technologies that facilitate communication between drivers. Because the research is in its early stages, it would be difficult to speculate about how the findings may inform the design of specific technologies. Regardless of the implementation, the integration of the AVACARS concept into the driving context would likely have important effects on safety and so this research will hopefully contribute to the guidelines for this endeavor.

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Design challenges for the 'Social Car'

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ABSTRACT
In this paper, we briefly describe our position and our recent activities in the domain of Social Car, giving our vision about what we consider interesting design challenges in the intersection between Social services and the automotive domain.

KEYWORDS
Automotive, Design, Social services.

1. INTRODUCTION
Social design is a recently emerged discipline within the broader user experience design, to study and define guidelines for shaping the experience of a product or a service in a more participated fashion. The study of design elements in huge online social services like Facebook and MySpace has led to a set of guidelines that designers can follow to conceive and design social experiences. Typically, design teams of the main actors into the social service domain do not release information about their design choices and processes [1].

2. BASIC ELEMENTS FOR SOCIAL SERVICES
Nevertheless, recently Facebook has released some hints and suggestions about the three main components for such services: the user community, the conversations between users, and the identities of the users themselves [2].

Users' community is central in the process of reputation building and is the entry point for the so called social context: lists of actions, statuses, information, and any other activities that through other friends show the status of the whole community and add relevance to individuals. Conversations (i.e. both the listening and communicating phases) represent all the interactions happening within the community. The identity is that particular element that is unique to each member of the platform and distinguish it from all the others.

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Adjunct Proceedings

3. EXISTING ATTEMPTS
The 'Social Car' is currently in the focus of all the main car makers, that recently have proposed and showed in shows and fairs their own concepts and platform to implement and connect to the main social frameworks. The majority of them, together with in-car entertainment appliances makers, embedded and mobile devices stakeholders, are converging towards the migration of their own existing solutions into integrated platforms, following diverse approaches, but whit a common goal: cover the largest possible spectrum of opportunities and increase the overall users' value of their cars. Several constrains are specific to the car environments, and therefore designers have to deal with more limits and restrictions, due to distractions' and privacy issues, that can have influence into the user interface devoted to interact with specific features for the 'Social Car' functionalities [3],[4],[5].

As an example, during latest CES 2012 in Las Vegas, several car makers like Mercedes Benz with its 2013 SL-Class model [7], have shown in-car platform able to connect and interact (with only a subset of functions, focused on the localization of friends) with Facebook. It was not possible to insert text messages, but just to select with touch screen interfaces (the same already used for in-car navigation systems) pre-sets messages, to avoid possible distractions.

BMW is proposing its own offer, called ConnectDrive, available on the Series 6, that with the BMW Live service allows drivers to benefit from a selection of services through the BMW Online platform [8]. IPhone owners can connect with Web radio stations and use Facebook and Twitter through the in-car interface.

TomTom since 2008 has been working with IQ Routes [10] and its crowdsourcing information gathering system. Rather than a social service, it is a system to collect information about traffic, accidents, and special events using a typical grassroots' mechanism and introduce participation and sharing ingredients, which are at the root of any social service.

Obviously, the quality of implementation of such social service within the car will be one of the buying 'drivers' that will influence people in the choice of their own new car.

4. DESIGN CHALLENGES
Rather than simply put Facebook in the car (or Foursquare, Twitter, etc.) or enhance a navigation system (like Waze [9]), mostly of the design challenges are related with the ability to

translate traditional elements of the identities, communities and conversations into the automotive domain [6].

What is the identity of a driver? What his/her elements of conversation? What can be valuable for joining a community or create a new one? Those questions are there to be answered to, not simply adding a 'Like' or 'Poke' button' on the deck, but carefully crafting new meanings, or right translating existing car-specific meaning into the new social environment. We are currently exploring this design space, during the very early stage of our research project. Just few examples about what we believe would be an interesting approach into this field, from a social designer's perspective:

- What can be learnt from the analysis of the existing communities of car modders and from the Xbox/Ps racing gamers?
- What can be learnt from existing car owners' practices, like the customization of the cars, from the choice of aftermarket accessories, to the decoration of interiors and external parts?
- How those practices can be somehow 'imported' into the new domain of the 'Social Car'?

We have started our research investigations only two months ago, beginning with a desktop research. Several examples and best practices are already on our table. Our initial activities considered separately the three components mentioned above: identities, communities and conversations. Through several brainstorming sessions we collect examples both from the 'social web' domain and from the automotive domain.

4.1 Identities in the 'Social Car' domain

If we think about existing social services like Facebook, Twitter and Instagram, their users can express their own identities into several ways: choosing a profile image and a cover image, or selecting a specific color scheme, or adding directly personal information on the public profile page. Another indirect way to shape the identity is possible through the status' updates, than rather than being only an element of a conversation, can also redefine and add details along time to the owner's identity. Within other services like Foursquare and Waze, the service itself can assign to the user special badges or awards that, above being the results of the user's actions, are also a way to make visible some of her/his attitudes, achievements, preferences and patterns, and therefore to add elements to the identity.

In the automotive domain, cars have always been a very special and powerful medium to communicate and express the identities of cars' owners. This is a very well recognized driver in the selection of the model and the brand of the car to buy. The spectrum of colors for the exteriors and the interiors of the car, and the availability of several optional elements to choose from, allow the car's buyer to consider her/his own new car as an 'unique' ensemble, made just for her/him. Other aftermarket solutions allow car's owners to customize them even more. Self-adhesive badges, stickers are other opportunities for personalizing the car and therefore communicating the owner's identity.

4.2 Communities in the 'Social Car' domain

Communities in existing social services grow around a shared interest, a preference, a specific attitude, a common ownership, or attribute (the birthplace, the hometown, the language, etc.).

As an example, an audiophile enthusiast can follow several forums, groups, pages on the same topic to exchange information, opinions, suggestions for new product to buy, new settings to test, etc. Each forum, each group, each page is a different kind of community, with its own rules, styles, goals and available actions. Moreover, communities can be parts of a bigger community, like the Instagramers within Instagram. Also the CHI community is a good example of such structure, organized in groups of interest and in local chapters.

Within the automotive domain, there are many different ways through which car's owners and drivers tend to gather and organize into groups or communities. To enlist few of them: historical cars' collectors, specific car models' owners (like Fiat 500), gentleman drivers and racing enthusiasts, professionals like taxi drivers, or truck drivers, 'veterans' of mythical routes like the Nordkapp: they can be open and public, or restricted with severe rules to apply. Other communities can grows around extreme behaviors and interests, like the extreme modification of the interiors and the exteriors of the car, or the passion for off-road adventures.

4.3 Conversations in the 'Social Car' domain

Conversations are made by all the elements that members of a community exchange with themselves. Within social services, they can go from simple status updates ('Dario is on his way to NYC'), simple actions ('Mario likes that link'), to more complex activities. They can go from adding a new checkpoint in Foursquare, to post a picture with the Instagram app on the IPhone; from sending an alert about a car accident with Waze, to interact with an app within the Facebook timeline. Obviously, they can be also short and long threads of messages, comments to messages, chats, private messages, etc., and any other combination of them.

In the automotive domain, conversations can be identified and described with a similar approach and in the same way: from adding a new badge on the back of the car, to the participation at an historical gathering; from the renewal of the subscription to a Club, to the information exchanged with friends about how to fix that peculiar mechanical problem. But there are other even more specific actions, activities and behaviors that can be thought as 'elements of a conversation', and that can be added easily into the conversations. As an example, when a car reaches its destination and stops the engine, it can send automatically a status update, like 'Dario just arrived in NYC' (this is one of the concepts developed within an "Hackathon" event during last spring, happened between two developers' teams from Facebook and Ford [11]).

5. DESIGN OPPORTUNITIES

How to express, make visible, and interact with all these elements in a car is a huge topic inside our research project. It will be our main focus for the next year of research. There are several design options and strategies on the table:

- Conceive new meanings to existing interactions and objects

- Define new way to display and visualize existing conversational elements or status updates
- Create new languages, grammars and etiquettes to be adopted within the new scenarios

While we are not ready to publish the early results available, we want to cite an interesting social media campaign happened in The Netherlands this year, the Volkswagen Fanwagen [12], full of suggestions and inspirations, especially about the approach adopted to mix and match of elements from the world of social services and of elements from the automotive domain.

Within a business perspective, some of the design options have well understandable patterns, already happening inside the automotive industry. For example: What to choose between several closed 'branded' platform or an open platform, available for all brands? By now, car makers try to propose their own platforms, while – reasonably - stakeholders coming from different markets and with different goals will embrace other approaches. This is another key opportunity in the development of new services and products that implement the 'Social Car' paradigm.

6. CONCLUSION

Other design opportunities will be reasonably discovered throughout the project. But we are interested also into exploring the benefit assessment: why should cars (maybe drivers) disclose their 'social status', their 'social relationships'? We believe that 'Social Car' is a design space full of opportunities, not only from a design research perspective, but also from a business perspective.

7. ACKNOWLEDGMENTS

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Applied Agency: Resolving Multiplexed Communication in Automobiles

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ABSTRACT
We explore the transition to greater sociability concerning automobiles in the context of communications being more fully integrated into their systems. We briefly examine the historical significance of past social technologies in cars and the relationship between synchronous and asynchronous communication technologies in the present. In particular, we examine the consequences of the emergent network that results from interaction between drivers, passengers, pedestrians and locations we call PolySocial Reality (PoSR), a conceptual model of the global interaction context within which people experience the social mobile web and other forms of communication. Based on this discussion, we suggest ways to enable more robust messaging in this context with a recommendation to enhance the agency and social awareness of software agents.

Categories and Subject Descriptors
H.1.2 [**Human Factors**]: Human information processing; J.4 [**Social and Behavioral Sciences**] Anthropology; B.4.3 [Interconnections (Subsystems)]: Asynchronous/synchronous operations; K.4.1 [**Public Policy Issues**]: Transborder data flow; K.4.3: [**Organizational Impacts**] Computer-supported collaborative work

General Terms
Design, Reliability, Security, Human Factors, Standardization, Theory.

Keywords
Automobiles, Social Media, Asynchronous communications, PolySocial Reality, Mobile Devices, Human Factors, Anthropology, Privacy, Security

1. INTRODUCTION
Early streets were inherently social, without automobiles. Although history would like to portray the introduction of automobiles to city streets and country roads as a friendly integration – early automobiles were rather anti-social to street life, often causing great divides between the public, who felt they had a right to streets, and automobiles, whose speed and power took them over. In part, this phenomena is illustrated by a montage of early clips from Harold Lloyd's 1928 film, 'Speedy.'[1]

The sociability of humans around automobiles at their beginning was that of being in conflict. People had opinions and fights regarding access of public streets and many tried to introduce legislation to protect themselves against automobiles [1]. This is echoed most recently in automobile/mobile phone regulation legislation where cars on the street play the part of the norm that is being taken over, and made more dangerous by those using mobile phones while driving. Today, we're designing embedded telecommunications technologies into the car, and in the process, making the car itself, in its entirety, a communications device. As to be expected, similar types of debates from history are being considered and opposed as were in the past. The ability of mobile technology to allow for both asynchronous and synchronous communication, without much of a noticeable time delay has resulted in multiple multiplexed communications scenarios. Our model of this is called PolySocial Reality (PoSR). In this paper, we explore the impact of PoSR on the next layer of integration of the automobile as a communications device in society, and in particular the need to develop software for the social automobile that encapsulates a concept of agency on the part of drivers and other automobiles.

The idea of a 'socially inspired' car is not new. Indeed, in the early introduction of automobiles, as documented by photos and films, cars were often set within highly social contexts: groups of people were called upon to right cars that had driven off the road, or that stalled in traffic and needed a crank to restart.[2] Automobiles that had running boards along their sides, invite youngsters to hitch rides down city streets.[3] Not everyone had a car, and in the early accounts, people were shown to share and help each other by offering rides or running errands for those who

[1] Driving Around New York City – 1928. Clip of scenes from Lloyd, H. (1928). Speedy. Uploaded by Aaron1912. Available from: http://www.youtube.com/watch?v=lkqz3lpUBp0 Accessed: October 5, 2012

[2] Old car. (2008) Photo of car being righted in 1930's. Uploaded by Darth Bengal. Available from: http://www.flickr.com/photos/darthbengal/3053814313/in/photostream/ Accessed: October 5, 2012

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were not as fortunate. Many early vehicles had open tops that were shown to encourage driver-to-driver communication, or communication with others on the city streets and sidewalks.

What really happened was much less idyllic: people fought automobile owners and drivers for control over the public streets and subsequently lost. It was a highly social process, but not social in the way that the streets were before automobiles. It was social in terms of conflict, opinion, discussion and politics, and was not necessarily polite, cooperative or peaceful.

> By the turn of the nineteenth century, streets were already shared by several sociotechnical systems. Private, horse-drawn vehicles and city services depended on them. Pedestrians, pushcart vendors, and children at play used them as well. The balance was always delicate and sometimes unstable, and crowds of automobiles soon disrupted it. During the 1910s and 1920s competitors fought to retain, or establish, legitimate title to the streets…Of the many street rivalries, the feud between pedestrians and motorists was the most relentless—and the deadliest. Blood on the pavement often marked their clashing perspectives…Their success or failure reflected not only the opinions but the fortunes of those who used them. Pedestrians forced from the street by aggressive motorists blamed the problem on spoiled "joy riders," and were in turn dismissed as boorish "jay walkers" by irritated drivers. [2:332]

Although at times unpleasant and at others deadly, this type of social communication shared a common trait: it was synchronous, happening in real time with people interacting in the same way. As cars were able to go at higher speeds and had a more robust architecture, they closed off and became even less social with the community (good or bad) outside their exteriors. Eventually, telecommunications devices became robust enough to be mobile. Radio phones, then Citizens Band (CB) radios, followed later by mobile phones entered the car environment and re-connected those inside vehicles to others outside their cars, who may or may not have been either on the road (as with CB radios and possible mobiles) or on land lines. In particular, the early days of CB radio had many parallels to the issues today of creating a 'socially inspired car.' According to Dannefer and Poushniky, CB radio usage created an anonymous, private (by anonymity), extended social network that gave people confidence that they could get access to help, traffic information, weather, police activities, etc. through communications with other members of the network. Anyone could purchase and use a CB radio, and while there was always the potential for criminal activity or betrayal of trust, it did not inhibit people from using the network. Trust was implicit by both having a CB and being a "Good Buddy" [3].

> The CB technology facilitates the expression of closeness, but it prevents its natural concomitant of commitment. This is so because the constraints placed upon behavior in repeated face-to-face interaction situations are absent. The overall impact of the technology has been to create a facade of strong social ties. Unfortunately, the social network thus produced is fragile. [3:616]

While CB radio communication was tenuous, due to its anonymous nature and lack of face-to-face interaction, it also happened only in synchronous time. The addition of mobile devices to the car enabled both synchronous and asynchronous communications, as well as documentation of where the call originated from, duration and so on. This removed privacy somewhat, but increased the robustness of trust. As phones became message enabled, communication between people using mobile or telephony technologies became more asynchronous and people communicated in a way that was time shifted, aided by the ability to send messages out with no knowledge of when they would be received or replied to and/or retrieve them at their leisure.

2. SOCIAL AUTOMOBILES

2.1 The Socially Inspired Car

The 'Transition to the Socially Inspired Car' might be titled the 'Return to the Socially Inspired Car' as we revisit and reinvent sociability through technologically assisted transportation. Sociability has different forms and at its foundation extends beyond our ability to communicate with one another to be social. Sociability is part of our survival strategy. To survive, humans must remember their dependence on each other for existence. Edward T. Hall wrote, "Man and his extensions constitute one interrelated system," [4]. As much as we'd like to separate that which is 'social' from that which is in the environment, we cannot, for these are interdependent [5].

Cars and people are already part of a highly complex interrelated social system that includes the infrastructure that they are dependent upon. This interactive social structure creates and maintains the systems that enable cars to function: streets and road repair, fuel, rubber for tires, oil, glass, metal, paint and other industries combine to make the idea of a running car even possible. When one is isolated in a comfortable car moving down a beautiful road, it is unlikely that the social structure required that makes the drive possible is even considered by the driver. If we add the potential for synchronous or asynchronous message communication to that driving experience, we can see that the interrelated social systems can get even more complex.

2.2 PolySocial Reality

We have suggested PolySocial Reality (PoSR) as a term for the conceptual model of the global interaction context within which people experience the social mobile web and other forms of communication [5;6] (see Figure 1.) PoSR describes the aggregate of all the experienced 'locations' and 'communications' of all individual people in multiple networks and/or locales at the same or different times. PoSR is based upon the core concept that dynamic relational structures emerge from the aggregate of multiplexed asynchronous or synchronous data creations of all individuals within the domain of networked, non-networked, and/or local experiences [7].

As an interaction context, PoSR has positive and negative outcomes. A potentially positive outcome may be an expanded social network; a negative outcome may be that those expanded social networks are connected by small, single dimension attributes. Another may be that the fragmentation of PoSR encourages individuation, which makes it more difficult for humans to be social (and cooperative) with one another, even as they effectively have a larger social network. While implementations continue to focus on individuated orientations, this can further compound that problem.

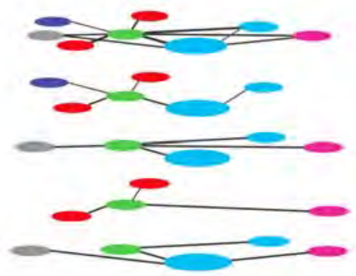

Figure 1. An 'exploded view' of a fragment of a PoSR network. Each layer represents a different social network of the same individuals, each based on a communication channel.

To the extent that people share common sources of information while interacting with each other, the greater their capacity to collaborate becomes. If they share too few channels relevant to a common goal, there may be too little mutual information about a transaction to interact and communicate well collaboratively. Poor collaborative interaction can lead to further relational fragmentation with the potential to promote individuation on a broad scale [8]. By changing the means that humans use to manage space and time during their daily routines, developers can shift our experience from individuated, user experiences to enhanced sociability within a multi-user, multiple application, multiplexed messaging PoSR environment.

If we consider the idea of PoSR in an automobile, we have multiple channels creating multiple communications, which may or may not be multiplexed, and receiving multiple communications in kind that may or may not be synchronous, all while moving, it can add up quickly to being overwhelming. This is evidence by the issues that have been legislated around the world regarding behavior in phones and driving, texting and in some cases even holding, a mobile device [9;10].

2.3 The Connected Car

Imagine someone driving on the road in a 'connected car.' They are being assisted by various on screen windshield AR applications that guide them through traffic, map their route and suggest places to stop along the way that they might want to visit. Furthermore, they still have the capability to make and answer calls, tell an agent how to respond to email etc. all while in-motion. They might be drinking a coffee or having a snack as well [11]. But that is not all of the challenges for the near future driver.

The battle for the territory for the car and its digital interior has just begun. In her essay, 'Connected cAR: Becoming the Cyborg Chauffeur,' the first author suggests that the way that cars are automating may be using human behavior to train the Artificial Intelligence (AI) of the car. At present, a human is still needed for nearly all automobiles and may start to be training the system as to the parameters of driving behavior.

> The car is apparently one of the next battlefields for ownership of our personal data and privacy. It is an intimate environment and there will soon be enough sensors to document every human habit and behavior within it. While cars will become the panoptic reporter to our every move, people will also be burdened with an overwhelming amount of data ostensibly aimed at 'aiding' them in the driving task. There will be touch activated windshields, Augmented Reality (AR) navigation lines projected onto the windshield that guide drivers on a track of navigation, and the blending of both scenarios with the addition of ads showing up on screen. Audio feedback based on sensor activity is currently available as a service in certain commercial vehicles. Installed sensors monitor driver behavior and provide immediate audio feedback if a driver changes lanes suddenly, is speeding or engages in other unsafe behaviors [11].

While an audio warning to remind people that their cars are weaving is useful, it does not fully address the issues that are required to keep cars safe with a multiple menu of digital, technological, and social options soon at their command. Cars are going to have to provide tools that simplify the decisions that both people and cars need to make to keep the car safe – if nothing else.

Sharing, or making a car more 'social' is certainly a double-edged idea. In one way, it can be similar to what happened in the later days of the automobile (after the turf wars for the streets had subsided) where 'social' behavior (as sharing) led to cooperation that helped the driver and, in turn, those that became passengers or were part of the community. In another sense, too much sharing does not benefit drivers or their communities, but instead that of advertisers, manufacturers, governments and so on. This is a less egalitarian view of sharing and sociability. If information is going to be exchanged between cars, authority, accountability, and the audit trail for when information is viewed and who gets to review it, will also need to be considered. Sharing information and coordinating vehicles enters people and their cars into a different kind of social relationship on the road. Not to mention the new opportunities for criminality as car hijackers/hackers find ways to control vehicles to overtake, steal, or utilize to aid them in their various schemes of either flat out theft or overtaking control of information systems to cause accidents...or worse [12].

3. MULTIPLEXED ATTENTION, AGENCY & SOFTWARE DEVELOPMENT

At present, humans are using mobile devices to extend their capabilities, often doing more than one thing at once. 'Divided Attention,' describes the state of humans focusing their attention on more than one thing at once. Research on divided attention suggests that people are not able to concentrate on other things in their vicinity when walking or driving whilst having a conversation that requires them to process information [13;14]. PoSR extends divided attention to even more extremes as the idea of PoSR multiplexes attention and creates a messaging environment that goes well beyond the physiological systems that enable people do things safely. Thus, the interaction environment described by PoSR poses great challenges to using upcoming technologies to improve the social integration of people and their vehicles, and the entropy of driving conditions combined with PoSR creates a complexity problem that requires a particular kind of Artificial Intelligence (AI) agency to solve. When cars have the potential to be 'social' (even between themselves as machine-to-machine) there exists a high potential for fragmentation due to PoSR related multiplexing. In hardware terms, the ability to parse multiple messages in an automobile is certainly possible. Sensors could be added to handle needed functionality and a processor could be dedicated to each thing that would give it undivided attention except for a few input settings. Software is another matter entirely.

Agency is the capacity to make nondeterministic choices from a set of options as events unfold. For example, humans exercise agency in a car when deciding to run a red light, or not, or to turn left and visit friends on the way to the store. The foundation of a social relationship requires the presumption of agency on the part of the other. Otherwise, it is not a social relationship; social relations require that each party assumes the other has agency. Presently cars do not have agency. Anti-lock brakes, airbags and other seemingly automatic features mimic agency in cars, but those are based on decision trees and will not scale to the multiplexed environment of a truly social car.

The capacity for both the human and machine to make genuine choices from a set of options as events unfold is the ideal outcome for a driving environment where events can be unpredictable. In other words, in the case of people within cars, the combination of humans/cars needs to have relatively successful outcomes in order to avoid accidents. The discussion of agency applied to PoSR and the social car comes into the fray not so much because we are concerned with the specific agency of an individual person or car but because to exercise agency in a social context, understanding that others have agency and a context for that agency is essential to an individual applying their own agency. We are suggesting that to be successful, the social car will require an AI that has operational agency in the sense that its own decisions are in part based on the presumption of agency. Bojic et. al. highlight some of the issues and problems relating to integrating machines into social networks [15:89]. However, although they include agency in their argument, they assume this is imposed from outside the social network, whose purpose is to realize this external agency, which is driving the global process as a series of distributed local processes. Manzalini et. al. anticipate the need for distributed agency-driven context awareness [16]. We argue that if there is more than one agency at play, necessarily these local processes must include a presumption of agency on the part of all interacting systems in order to resolve the often conflicting goals of different agencies.

The problem lies in having to manage any loss of information that comes about by distributing the messages across too many different networks. When people do not know enough of the context of the people they are communicating with, they have the potential to make wrong inferences. When communicating in person, people infer things based on many inputs, including observations, which enable them to understand how the other person is situated. When the other person in a communications transaction is situated doing different things that the observer is not aware of, due to being in another car, city, state or country, the initial observer needs to learn to make more conservative estimates of their inferences, or they will be at risk of making wrong judgments. As a rule, more general inferences are less tailored to specific individuals (and situations) and are not necessarily the most accurate or the most efficient. Generalized inferences do not work as well as more tuned coordinated social interchanges. This kind of impact of fragmentation in PoSR could easily happen in an engineering sense: messages, the foundation of sociability, require observations and other data to produce accurate inferences and judgments for successful communication and in turn, successful cooperation.

When observational cues are absent, more conservative general estimates must be made. It is not a hardware problem, the hardware can process whatever it needs to in a vehicle in terms of data, but software is difficult to write because unless there is some type of corrective for contextual interpretation, more conservative judgments will need to be made, which in turn means less efficient/accurate/appropriate judgments, which in turn reduces the scope of what can be accomplished. In a car that is monitoring many different sensor inputs plus potential multiple, multiplexed social messages that contribute to interpretations of PoSR context, plus its own agency, the event of one message interpreted poorly could have disastrous results. This problem also makes it difficult to certify such a system because in order to certify it, nearly all of the local inferences will need to be as close to 100% reliable as possible. Due to variability of interpretations in PoSR with respect to multiplexed messaging from a hypothetically huge number of vehicles on the roads, this becomes nearly impossible.

This complexity problem emerges from a combination of agency, volume of messages and the context of the messages that are both coming in and being sent out to other people and vehicles. Not all messages are available to all segments at all times and an incomplete distribution of the messages creates more confusion, as it is impractical to send everyone every message and expect them to process the data.

Because there only needs to be one message that is not properly contextually transmitted or interpreted for a disastrous result, particularly in an automobile, accounting for a broader range of activities that are happening at any given time will have to be designed into the system. In other words, PoSR contexts might be alleviated somewhat, if the different network members knew something about what other networks each is involved in. Solutions might include agents that summarize different things for different parts of the communications to create more accurate interpretations of messages or to design less efficient systems. What may be a possible solution, in part, is to produce some kind of subsystem that manages context within PoSR. A system of 'tokens' could develop for each context and could be transmitted with messages. These could be collected as they flow across more and more networks. Thus, producing a contextual history that is attached to the communications, allowing for the development of more agency on the part of the system.

4. CONCLUSION

A useful means of representing PoSR contexts might include creating some form of dynamic commentary regarding an element's context that is constructed from any combination of visual, aural or language-based elements that can be modified, rescaled and browsed by end users to find information they require from the present or past about others they are interacting with directly or indirectly in a compact form [7].

Appropriate descriptions of PoSR contexts may offer location aware applications a tractable means of traversing the complexity of single and multiple user experiences while maintaining the complexity required by users (and cars) to construct further applications of the technologies they employ [7].

Highly heterogeneous messaging environments that enable individuals and their cars and/or individuals in cars and their passengers, to connect and communicate with each other and others, can lead to a complex situation that has little overlap for cooperation [8]. This will be especially challenging as the hardware form factor migrates to a head-mounted glasses option.

Without restricting the possibilities for PoSR communication, software development that enlists the use of Agents for certain processes and tasks may help to restore 'order' in the car. It has been documented that having connection in the car (via the CB radio research [3], and as evidenced by the overwhelming usage of mobile phones and texting while driving [3]) to systems outside the car [11], is important and valuable for humans. It is worth further exploration to determine if social needs within vehicles remain the same from the CB radio days, or have changed with the times. Furthermore, as the car becomes a fully automated (pardon the pun) form with Artificial Intelligence eventually replacing the human driver, planning for how it will handle the complex multiplexed environment of communications that emerges as PoSR, along with its own newfound agency, within its environment is critical.

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"Yes, Free Parking Lot App, No, Invisible Health Check App in My Car": Young Drivers' Needs Analysis on Vehicle Area Network Services

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ABSTRACT

Recently, automobile researchers and practitioners have spurred research on vehicle area network (VAN). To create user-centered services instead of technology-driven services, involving users in the early design stage is important. To this end, we conducted focused group interviews with young drivers for user needs analysis. The present paper focuses more on describing drivers' qualitative comments and concerns about plausible vehicle area network service concepts [1, 2]. This explorative study is expected to contribute to guiding researchers in academia and practitioners in industry to translate user needs into service requirements so that they could balance users' needs and the use of potential technologies in service implementation.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**] User/Machine Systems – Human factors.

H.5.2. **[Information Interfaces and Presentation (e.g., HCI)]**: User Interfaces – user-centered design

General Terms

Design, Human Factors

Keywords

Focused group interview; participatory design; VAN (vehicle area network) services

1. INTRODUCTION

Thanks to advances in network technologies and changing perception about the role of vehicles, we can see a proliferation of vehicle area network (VAN) or car-to-car projects led by government, industry, or academia [3-5]. Indeed, cars are becoming "personal communication centers" [6]. The present study details young drivers' needs, wants, and concerns about diverse VAN service concepts.

1.1 VAN Service Concepts

The term, 'VAN' has been broadly used, including V2I: Vehicle-to-Infrastructure, V2V: Vehicle-to-Vehicle, V2B: Vehicle-to-Business, and IV: Intelligent Vehicle [7]. Based on this taxonomy, we created various VAN service concepts and classified them as follows [1-2]: V2I - Intelligent Traffic Guide, Free Parking Slot/ Parked Car Finder, Sensory Bubble, Ambient Awareness Ads; V2V - Awareness of Others & Their Intentions, Drivers' Networking; V2B - Drive-by-Payments, Home Networking, Entertainment on Demand, Nomadic Workstation, Broadcast Your Driving Environment, IV - In-Vehicle Driver Status Monitor (Fatigue/Emotion), Route Buddy, Collaborative Driving, Green Speedometer/ Peripheral Auditory Displays, etc. For more details on each service concept, see [2].

2. FOCUSED GROUP INTERVIEW

2.1 Session Procedure

Using those concepts above, we conducted five focused group interview (FGI) sessions with licensed young drivers (10 female and 8 male; mean age = 20.5; mean driving = 5 years). The session consisted of two parts. In the first part, participants discussed several topics that researchers prepared: purpose of using their car, necessary information while driving, bad experiences in a car, the use and possible needs of rear seats, activities with passengers, plausible near future in-vehicle technologies, etc. In the second part, researchers demonstrated VAN service concepts using Microsoft Power Point with detailed usage scenarios and obtained participants' comments on each idea. The present paper focuses on the qualitative data obtained across sessions. For quantitative data analysis, see [1-2].

2.2 Young Driver's Vehicle Usage

Among interesting responses gathered during the FGI sessions, we highlighted a few answers here. As bad experiences in their car, our participants stated, 'not able to use the car for transporting huge stuffs', 'trouble when another car parked too closely', 'the car stalls while in use', 'runs out of water in tank', 'hydroplaning', 'a battery going dead', and 'driving in snow', some of which might be tackled by VAN services.

When they get sleepy or tired while driving, the participants turn on louder music, switch types of music, sing on their own, talk to people, call people on speaker phone, stop for a (coffee) break, roll the windows down, have a cigarette, or drink and eat.

Reflecting their coping strategies, VAN services could contribute to that frequent and critical situation in various ways.

Common activities conducted in the passenger seat or the backseat area involved sleeping, controlling music, aiding navigation, playing games, or socializing with other people in the car. Currently, technologies used in the backseat contained turning off the speakers, watching TV using screens in the back, adjusting tint in the car, or warming seat in winter. They also wanted more comfortable space and iPod chargers. Additional information the participants wished from their car included miles per gallon (i.e., miles left before you fill up), traffic updates, navigation system, sending text messages, access to the Google Maps or the MapQuest, blind spot information, weather conditions, and overall friction in the tires, etc.

Here are participants' thoughts about how future technologies could support positive experiences in their car: a car that drives itself and auto-park themselves, getting your work done while in the car, relaxation during long trips, communication between other cars to avoid accidents (e.g., cars brake on nearing a car before), a car having spatial perception, a better working internet (satellite) with high availability, a car tells a driver to check air pressure and other status, etc.

In short, young drivers clearly showed that they have motivations for a better network, communications with other drivers or cars, and vehicle's self-diagnosis. Researchers and designers could start their concept making, not only from users' wish list of the technologies, but also from their bad experiences in a car to overcome those issues via VAN services.

2.3 Young Driver's Comments & Concerns about VAN Services

In the second part of the session, participants were shown and explained about the details of the VAN service concepts and asked to discuss issues and suggest ideas and usage scenarios. Even though all of the participants were young students at the technological university, they showed balanced perspectives on the use of technology in a car rather than having blind faith about technology.

Yellow Signal Helper In some groups, the participants felt it is useful and they would use it. A participant suggested adding some visual alerts, such as lights on the dashboard in addition to audio alerts. In other groups, some participants noted that they would make their own judgment, rather than depending on the system. Others were concerned about a driver's confusion due to too much information or reverse effects of rebellious people. Additional considerations included the different length of the yellow light in a different location, timing of the system alert, the distance from the signal, and system's awareness of a driver' turning direction or reaction time data.

Awareness of Others & Their Intentions Some participants reported that it could be useful in a highway when cars cut right across a driver. However, most of the participants suspected its feasibility based on the current technology and they worried about distraction caused by using this service. Also, they pointed out that increasing dependency on this service might allow drivers not to pay attention to the road, which accords with previous research that shows automation will decrease driver situation awareness [8].

Free Parking Slot Finder Some of our participants were aware of this type of smart phone apps, (e.g., 'where is my car'), but they found that the current apps have an accuracy issue. Whereas most participants agreed to the need of this type of service, they were skeptical about people's voluntary marking or registration for it. Instead, they believed that this service should be implemented based on sensors in the parking spot itself. Sizes of cars and handicapped parking lots should also be considered in design.

Drive-by-Payments The first concern regarding this concept is a security issue (e.g., 'everyone in the car might look at the password', 'signals could be intercepted while making payments'). With guaranteed security, participants would favor it. They added some scenarios, such as dry-cleaning payments, amusement parks, in addition to all cases of parking. A participant commented, if it becomes more widespread, it would be more useful.

Steering Wheel Alerts There were some concerns about using color displays on the wheel, but many more ideas were obtained for the use of steering wheel alerts, including low/empty gas, exceeded speed limit, not wearing a seat belt, checking an engine. Another idea is just the use of the steering wheel as a simple binary alert for drivers to check the dashboard for the details. However, a participant brought up another issue that haptic feedback using vibration could scare people when they are already stressed out. Most of the participants specifically liked the idea of a hand warmer (in winter) and cooler (in summer) in addition to alerts.

Steering Wheel Heart Rate Monitor/ Invisible Health Check Some people found that it is an interesting idea, but most participants thought that it may not be generically useful for everybody. However, they were positive about the use of this type of service as an option for some specific populations, such as old adults or people with health risks. Privacy concerns should be considered.

Fatigue Meter/ Emotion Detection Commonly, participants were worried about a driver's over-reliance on the system. Regarding the fatigue meter, they were relatively positive and recommended using it for a truck driver who has to have long drives regularly. In contrast, some participants were more sensitive to the emotion detection concept than the fatigue meter or previous health monitoring concepts. One participant warned that this type of service could influence a driver's emotional status in a negative way. Nevertheless, they agreed to use this system to prevent road rage.

Route Buddy Participants found the most useful case for the memory and notification of the location of the police car. Some said that it could be helpful for speeding, but others believed that it might be more useful for potholes and wrecks rather than stop signs or speed limits. Novice or student drivers could benefit from this type of system.

Home Networking/ Entertainment on Demand Turning on (before you get home) or turning off home appliances (stove or hair straightener, etc) might be useful, but the participants considered those cases as a backup rather than using it on a regular basis. They also stated that it would be more useful for old adults rather than young adults. It seemed that usability matters here. Several participants gave concerned about the plausible complication of the control. Other issues included authentication and security threats (e.g., "make sure if car gets stolen, then the thief can't access your whole house.").

Nomadic Workstation Some participants favored this idea in terms of more efficient use of their time. They stated a couple of plausible situations where people could benefit from this service, such as rush hour or vacations. Others were worried about chances of distraction caused by additional works while driving and mentioned that it could/should be for passengers only, not drivers.

Drivers' Networking (Plate Tells about You) For this service concept, various issues including security, privacy, and controllability were brought up (e.g., 'random people can know where you are going', 'celebrity's car likely to be spammed'). The participants were concerned about the technology abuse by people. Additionally, they were curious about technological issues such as the range of proximity and plausible protocols. Some participants would allow asking for directions, but others would not want to share their own music with other drivers.

Global Profile/ Ambient Awareness Ads One of the most critical issues regarding these services was customizability. No one would have automatic allowance (information 'push'), but the participants wanted to have options for selecting type and amount of information and turning it on and off (information 'pull'). Otherwise, they expected that the service could be spamming and cause information overload. An interesting suggestion was to have an interactive assistant that figures out a driver's current needs.

Broadcast Your Driving Environment Again, the only one comment about this concept was a usability issue. They want an 'easy to use', 'not distracting' service.

Green Speedometer/ Peripheral Auditory Displays Given that these services are not directly related to a safety issue, most participants were positive (e.g., "this could really make people aware of their wasteful tendencies," "good for a niche market"). All of our participants listen to their music while driving, and thus, the practical issue was brought up about peripheral auditory displays (e.g., "visual color is nice, but I don't think many people will listen to 'good music'. They would rather listen to their own music").

3. CONCLUSION

The current paper analyzed young drivers' needs and wants as one of the participatory design processes to draw refined concepts of the near future vehicle area network services. Through multiple focused group interview sessions, we obtained elaborated ideas, scenarios, and young drivers' critical concerns about plausible services. If any service is launched merely based on technological possibilities, without any user inputs, it might result in huge redesign or maintenance cost. Even though several concepts obtained good feedback from young drivers, it is still needed to address remaining user experience issues and system issues in the next research phase. A couple of on-going VAN projects [3-5] are expected to provide more practical guidelines about potential issues and validate service concepts on the road.

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Appendix

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Keyword Terms

Technical Program Committee Members

We very much appreciate and warmly thank many people who have worked to make this conference possible. We recognize and appreciate all the work the Technical Program Committee members and additional expert reviewers put in to promote the conference, review papers, and select the work that composes these proceedings. In addition, this workshop's chairs appreciate the support from the University of New Hampshire and the AutoUI workshop chairs.

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Portsmouth, New Hampshire, US

Workshop „Human Factors for Connected Vehicles: Planned Research and Guideline Development Activities“

Workshop Organizers:

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Monica G. Lichty	Battelle, Seattle, WA
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Human Factors for Connected Vehicles Workshop: Planned Research and Guideline Development Activities

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ABSTRACT
The United States Department of Transportation's (USDOT) Connected Vehicle program includes a human factors research component (Human Factors for Connected Vehicles, or HFCV) that will examine ways to increase safety and reduce the frequency of crashes caused by driver distraction. A key outcome of the HFCV program will be a set of guidelines for the development of the driver-vehicle interfaces (DVIs) of Connected Vehicles. This workshop will provide an overview of the DOTs HFCV program, review key research studies underway to support the program, describe the process of developing design guidelines for the HFCV program, and identify opportunities for industry stakeholders to participate in the effort.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Standardization; H.5.2 [**User Interfaces]:** Style guides; H.5.2 [**User Interfaces**]: Graphical user interfaces (GUI)

General Terms
Human Factors

Keywords
Connected vehicles, Human factors guidelines, Integration

1. INTRODUCTION
Connected Vehicles (CV) is both a concept and a program that combines leading advanced technologies, including on-board computer, dedicated short range vehicle-to-vehicle communication, sensors, Global Positioning System (GPS) navigation, and smart infrastructure technologies. A goal of the Connected Vehicles effort is to identify threats, hazards, and delays on the roadway, and to provide drivers with alerts, warnings, and real time roadway information. A more complete description of the United States Department of Transportation's (USDOT) efforts in the Connected Vehicle area can be found at http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm.

The stated goal of the human factors portion of this program is to *"ensure that the use of connected vehicles technologies do not introduce unforeseen or unintended safety problems"* (see also http://www.its.dot.gov/connected_vehicle/human_factors.htm). A key element of the human factors effort is a plan to produce guidelines to support the development of the driver-vehicle interfaces (DVIs) of Connected Vehicles. These guidelines will enable developers and manufacturers of DVIs to minimize the unintended consequences of such devices and ensure that they are constructed to be compatible with driver limitations and capabilities (i.e., safe for use in the vehicle).

2. GOAL OF THE WORKSHOP

The goal of the proposed workshop is to fully communicate the objective, research components, and guideline development activities of the HFCV program to the automotive research and design community, and to invite their feedback and participation in the effort.

3. TOPICS OF INTEREST

Expected participants would be individuals with experience and backgrounds in vehicle design, automotive safety, or human factors. The preferred number of participants would be 20-40.

Scheduled topics will include:

- Overview of the HFCV Program (NHTSA Staff)
- Presentations on a variety of HFCV research studies, including Crash Warning Interface Metrics (CWIM), DVI Design, and Integration
- Guideline Development Activities
- Group discussions or breakout groups on key topics (e.g., individual research areas, guideline development)

We would publicize the workshop with a website and through e-mails to critical individuals and groups (e.g., the SAE Safety and Human Factors Community). Reports from breakout groups would be documented and provided to NHTSA for future consideration.

4. ORGANIZER BIOGRAPHIES

John L. Campbell is a Research Leader at Battelle's Center for Human Performance and Safety (CHPS) in Seattle, Washington. Since joining Battelle in 1994, Dr. Campbell has been responsible for leading programs and conducting research in the area of transportation human factors and driver safety, with an emphasis on the design and evaluation of advanced driver information systems. In addition to his research and development responsibilities, he is the Director of the CHPS Human Performance Laboratory.

Christian M. Richard is a Principal Research Scientist at Battelle's Center for Human Performance and Safety (CHPS) in Seattle, Washington. Dr. Richard has formal training in human cognition, perception and attention, human aging, psychophysiology, research design, and statistics. He has been actively involved in empirical and analytical research activities in the area of human factors since 1999. Dr. Richard has served as principal investigator on human factors projects related to Highway safety and Pipeline Control Room safety, in addition to product design and evaluation for Automotive Industry clients. Dr. Richard also has extensive experience developing human factors guidelines for roadway systems, in-vehicle collision-avoidance systems, and in-vehicle "infotainment" systems. He has led several technical efforts involving conducting naturalistic driving data collection, literature reviews and investigating traffic-safety related human factors from the road-users perspective, including intersection safety, speeding behavior, vision/attention requirements in driving, driver distraction, and fitness to drive.

Monica G. Lichty is a Researcher in Battelle's Center for Human Performance and Safety (CHPS) in Seattle, Washington. Ms. Lichty has formal training in human factors analysis of products, websites, multimodal interfaces, and complex systems. Ms. Lichty has experience with all aspects of human factors guideline development including literature searches, research reviews, guideline development, and graphic generation. Recent efforts include guidelines for road weather information dissemination and road systems. She has led and contributed to technical activities including driving task analyses, focus group data collection and analysis, group data collection sessions, statistical analyses, and crash warning system DVI evaluations. Research topics for these activities include complex interchanges, roundabout navigation, naturalistic driving, and speeding.

James Jenness is a Senior Research Scientist in Westat's Transportation and Safety Research Group. He leads the Westat research team for NHTSA's Human Factors for Connected Vehicles program. This team is investigating a range of issues related DVI design and ways to minimize driver distraction and other unintended consequences. Many of Dr. Jenness' past projects have focused on the behavioral effects of introducing new in-vehicle and infrastructure-based technologies for drivers, motorcyclists, and pedestrians.

Neil Lerner is Manager of Human Factors for Westat's Transportation and Safety Research Group. Dr. Lerner leads a multi-organizational team for NHTSA's Crash Warning Interface Metrics (CWIM) program, which is developing evaluation protocols and design guidance for crash warning interfaces (specifically Forward Collision Warning and Lane Departure Warning). He has also led activities within the Connected Vehicle Program. In numerous past projects he has developed guidance for driver interface, ITS displays, road systems, driver information systems, and others sorts of products.

Zachary Doerzaph is the leader of the Connected Vehicle Systems group at the Virginia Tech Transportation Institute (VTTI). Dr. Doerzaph has 10 years of experience in advanced safety systems and connected-vehicle projects. Notable projects for which he has served as a Principal Investigator include the Human Factors for Connected Vehicle Systems projects sponsored by NHTSA; the Safety Pilot Driver Clinics Supervisor and Model Deployment projects sponsored by the Collision Avoidance Metrics Partnership (CAMP); the Naturalistic Motorcycle Study sponsored by the Motorcycle Safety Foundation; and several data analysis projects utilizing VTTI's large-scale naturalistic driving data sets as well as numerous proprietary studies for OEMs testing and developing collision avoidance and semi-autonomous vehicles. In general, Dr. Doerzaph focuses his efforts on the design, development, and evaluation of advanced vehicle systems such as connected vehicles, collision avoidance, autonomous vehicles, and driver behavior monitoring systems. Dr. Doerzaph is knowledgeable in large-scale system integration and has considerable training and hands-on experience with vehicle design, data acquisition and integration, and large-scale database analysis.

Christian Jerome is a Research Psychologist in the Human Factors/Engineering Integration Division at the National Highway Traffic Safety Administration. He provides technical program, project, and task management, including monitoring technical and financial progress, for all HFCV projects. Dr. Jerome has co-authored many publications on traffic safety research topics including driver distraction, driver workload, age-related driving issues, and orienting attention to hazards or threats in the environment, many of which were presented at conferences and workshops.

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Portsmouth, New Hampshire, US

Workshop „We are not there yet: Enhancing the "Routine Drives" Experience“

Workshop Organizers:

Carlos Montesinos	Intel Corporation
Dalila Szostak	Intel Corporation

We are not there yet: Enhancing the "Routine Drives" Experience

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ABSTRACT
Grand Theft Auto and The Italian Job might be the most exciting things that we currently experience in driving. Day in and out driving is mundane, repetitive and highly routinely. Through our ethnographic research, performed in Germany, Brazil, and China, we have identified this notion together with several design opportunities in the area of future automotive user interfaces. In this workshop we open the doors to explore the 'Routine Drives' experience space. This research, together with statistical information about driving patterns, as well automotive technology trends makes exploring this space in a new light highly relevant. Through hands-on activities, presentations, and discussions, we would like to investigate such space with practitioner and academic peers in order to make the -boring and mundane- attractive, entertaining and engaging.

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
Ethnography, GPS, Smartphone, Map, Design Spaces, Interview, Automobility, Routine Drives, Congested Traffic.

1. INTRODUCTION
Ethnographic research methods are foundational to exploring the design space of automotive user interfaces. In the Local Experiences of Automobility (LEAM) project, we used these methods to explore mundane small moments, repeated practices and taken-for-granted decisions that make up daily experiences. The LEAM project, first outlined at Auto UI 2011 [1], was conducted in three leading car markets: China, Brazil and Germany. The research protocol included two in-home semi-structured ethnographic interviews around a one month data collection period. Sources of data included an application monitor installed on the participant's Android smart phone and sensors that were placed in their primary vehicle: a passive recording GPS, sound pressure sensors, light sensors, accelerometers and temperature sensors. One of the outcomes of this research has been the identification of six design dimensions: Averting Risks, Routine Drives, Brought-In Technology, Motionless, Stuff in Cars, and Shared Roads. These dimensions allow us to generate multiple design possibilities and technical solutions around smart transportation and user interfaces, yet remain grounded in current lived experiences of automobility.

With this workshop we would like to focus our attention in the design space of Routine Drives. This space was determined from both qualitative and quantitative data, after observing how driving is mundane and highly repetitive. We witnessed how people make the same trips and go to the same places, often at regular intervals. In general, daily commute driving is boring, unexciting and dull. Additionally, we found out that the majority of the time spent in the vehicle is made up of short trips (most of them lasting less than 10 minutes). It is of interest to note that during these trips drivers rarely need directions or extensive entertainment, which is what current in-vehicle infotainment (IVI) systems provide. The US mirrors the data collected in Germany, Brazil and China as well. For example, the US Department of Transportation states that out of the total amount of time that people spend behind the wheel (about 87 minutes) the majority of it is spent in daily commutes (about 60 minutes)[2]. This information, coupled with the assumption that the amount of technologies, sensors, and computing systems will only continue to increase in vehicles, makes the opportunity space to explore the Routine Driving experience in a new light highly relevant. The goal of this workshop is to bring together experts from the industrial and scientific domain to re-evaluate how we currently think about the time spent in the car, to imagine a completely new experience and to translate those findings into tangible solutions to share with the community as a first step. More specifically, we would like to invite our peers to think about this design space as follows:

1. How can knowledge of routine journeys affect the way we design the overall in-car experience?
2. How do we design in-car experiences that extend beyond a single drive and unfold over multiple repetitive drives?
3. What are the elements that can help enhance the experience of sitting in congested traffic?
4. Is there an opportunity to have an active role to directly reduce the amount of congested traffic?
5. What technical elements could contribute to shaping this experience beyond navigation and entertainment?

The workshop will also provide an opening to move beyond the discussion area by inviting participants to brainstorm and quickly prototype the challenges and opportunities associated with the design space.

2. WORKSHOP STRUCTURE
The proposed format for the workshop consists on a full-day session (~6 hours). The workshop will be made up of: presentations, discussions, and a hands-on activity.

2.1 Presentations
We will kick off the workshop by providing time for quick introductions of participants as well as presentations of their current work, areas of interest related to the topic, as well as their submitted position paper.

2.2 Discussions
We will quickly transition to a group discussion about the views on Routine Drives, highlighting the areas of importance related to the challenges and opportunity spaces.

2.3 Hands-on activity
Breaking the group into smaller teams, participants will be challenged to deliberate in their groups and construct a solution that delivers, in a tangible way, what their views are related to an ideal experience in the frame of Routine Drives. Examples of the desired outcomes include rapid prototypes built with tools such as: paper, Arduino, Processing, video, etc. Workshop organizers will provide basic supplies and tools, and participants will be encouraged to bring their own. Teams will be constructed carefully selecting attendees with different backgrounds to create a truly multidisciplinary solution.

Finally, all the teams will have time to present their artifact to the group to generate discussion and define next steps.

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. Interested workshop participants will be requested to submit a 1-3 page position paper on one of the design questions listed in the introduction. Answers can be theoretical or empirical (prototypes, studies, applications, or interaction concepts) and should be innovative in nature. The paper should also contain a short bio of the author highlighting the relevant areas of interest, current work or research. The selection of workshop participants will be done by a review process by experts from the broader field of automotive: anthropologists, computer scientists, interaction designers and human factors engineers acting as reviewers. Reviews will be done anonymously using an evaluation form. The submission process, as well as 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. Social networks will also be utilized for this purpose.

4. EXPECTED OUTCOMES
By the end of the workshop, attendees will come away with a deeper understanding of the design space of routine driving and all the opportunities this represents, by being exposed to an initial set of solutions to enhance the experience. We expect that these efforts will help identify the areas that would benefit from furtherresearch, that they will be able to carry the results of the discussions and use them in their future work. We also aim to contribute with articles in publications of interest, documenting the workshop findings and potentially including a gallery of all the prototypes created by the group.

5. ORGANIZERS BIOGRAPHIES
5.1 Carlos Montesinos
Technology Researcher in the Interaction and Experience Research (IXR) Group, Intel Labs. His main role is to develop technologies to bridge the interaction gap between people and computing systems, and his research focus is in Human Computer Interaction (HCI) for Automotive. Carlos received his B.S. in Electrical Engineering from Universidad San Francisco de Quito, Ecuador, and he earned his M.S. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign. Prior to joining Intel Labs he worked as a Test R&D Engineer with Intel Manufacturing, developing and validating Robotic prototypes for Intel's automated factories. Carlos has contributed with multiple projects in Robotics and Controls in Germany, Japan, and Ecuador.

5.2 Dalila Szostak
Human Factors Engineer in the Interaction and Experience Research (IXR) Group, Intel Labs. Her work is focused in experience design and evaluation to guide a people focused vision for new Intel products in particular in the area of automotive. Dalila holds a Professional Doctorate in Engineering in the topic of User System Interaction from the Technical University of Eindhoven, The Netherlands and a MS in Human Factors and Systems from Embry Riddle Aeronautical University. Prior to joining Intel Labs, Dalila worked with Boeing Commercial Aviation division in the role of Human Factors Engineer and with TomTom in the role of Interaction Designer (User Experience team).

5.3 Alex Zafiroglu
Senior researcher with the Interaction and Experience Research (IXR) Group, Intel Labs, where she researches the complex relationships among people, spaces, and objects in car settings, and the kinds of experiences of technology that make sense in such space. She received her Ph.D. degree in Cultural Anthropology from Brown University in 2004.

6. ACKNOWLEDGMENTS
In addition to the authors, Victoria Fang, Jennifer Healey, Tim Plowman, David Graumann, and Brent Selmins are part of the Intelligent Systems research group in the Interaction and Experience Research Lab.

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Routine Driving Infotainment App: Gamification of Performance Driving

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ABSTRACT
Infotainment apps are software that combines information and entertainment. We propose them as a means for mitigating the tedium of routine drives. This paper explores the use of gamification and performance driving as design elements of an infotainment app that can transform the boring and mundane aspects of routine drives into productive, entertaining, engaging, and fun experiences. The app is a performance driving game called 'Driving Miss Daisy' [5]. We draw similarities in task and situation between performance driving and routine drives and suggest using performance driving as an information theme for the app. When played in the natural course of driving on the same trips to the same places, the sessions form the basis of multiple game plays (i.e., repeated practice) that lead to mastery of good car control skills. Aside from the education and productive elements, the game is designed to entertain and engage..

Categories and Subject Descriptors
H.5.2. [Information interfaces and presentation]: User Interfaces; K.8.0 [Personal Computing]: Games.

General Terms
Your general terms must be any of the following 16 designated terms: Algorithms, Management, Measurement, Documentation, Performance, Design, Economics, Reliability, Experimentation, Security, Human Factors, Standardization, Languages, Theory, Legal Aspects, Verification.

Keywords
Experience, gamification, in-vehicle infotainment, performance driving, skill mastery.

1. INTRODUCTION
Automobile manufacturers are exploring in-vehicle ways to make the journey less boring. One approach is to translate information about physical driving parameters into vivid animation. For example, the Chevrolet Volt's 'Driver Information Center' displays a ball that animates and changes color (e.g., yellow for sudden braking) based on a car's acceleration or deceleration [4]. Information media that make an intentional effort to entertain are known as infotainment apps.

Routine drives are familiar and repetitive as they relate to driving behavior and driving route. By their nature, they are a task whose performance can be fairly automated. For the driver, this can be boring and it is a situation ripe for infotainment. Performance driving is driver training focused on developing optimal vehicle handling skills appropriate to the road terrain [9]. By their nature, the training involves repetition and practice of driving over a set course.

As a driving task, performance driving shares similar task and situational characteristics with routine driving. Thus, performance driving can provide the informational component for an infotainment app for routine drives. When combined with gamification [3], we have the entertainment component for the app. Tying entertainment to the informational presentation of the driver's performance can offer two benefits to the driver: a) relieve the tedium of driving and b) give real-time feedback of how well the driver is driving. This paper explores a novel way of entertaining drivers during routine drives by designing a performance driving competition game that uses the routine drives as the game context.

2. GAME FLOW
The game, named 'Driving Miss Daisy', chooses the game level for the players based on their previous performance. For a new player, the game begins with the 'easy' level that sets a higher triggering threshold for bad driving behavior and a lower triggering threshold for good driving behavior. The goal for the player is to drive a virtual passenger, Miss Daisy, to the destination safely and smoothly and to avoid hazardous and uncomfortable maneuvers like sudden braking (see Figure 1). When a drive ends, the player is given a summary of her trip and performance. She is also told how her performance compares to others on the same route (see Figure 2).

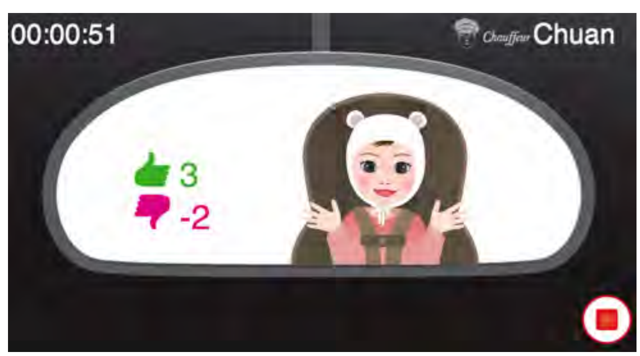

Figure 1. Driving Miss Daisy Display.

3. OUR GOALS

The design of the game app has three main goals. First, the game makes routine drives fun, entertaining and engaging experiences. Second, the game is focused on developing car control skills and therefore drivers should not be less cautious in driving due to playing our game. Third, the bonus aspect of the game is that it turns routine drives into productive and educational experiences where drivers can improve their driving performances in the course of playing the game repeatedly.

Figure 2. Game summary presented at end of drive.

4. GAME DESIGN

To achieve the goal of being entertaining, the app uses several game design strategies. First, the game is a role-playing game. Our game's backstory is inspired by the movie 'Driving Miss Daisy' [5]. Miss Daisy is a virtual passenger and the player is the driver and her chauffeur. She occasionally comments on the chauffeur's real and actual driving performance. Audio feedback is primarily used so that drivers do not need to constantly attend to the display [1].Our Miss Daisy is a young girl to make the character and the audio effect cute and playful. Different audio feedback snippets are mapped to each action for variety. More generally, our design envisions different persona for Miss Daisy; each persona offers different ways to entertain and models different feedback caricatures.

Second, reward mechanisms are incorporated to motivate user engagement. The game monitors smooth and hazardous driving performance. Smooth driving performance includes constant driving speed for a period of time (aka cruise control), driving within speed limit, smooth acceleration and deceleration of the vehicle, and smooth cornering. Hazardous driving includes going over the speed limit, sudden starts and stops, sharp cornering, and erratic lane changes. Our initial prototype implements all but the cornering and lane changes.

Third, competition is added to increase fun and engagement for players. More importantly, the game promotes good car-control skills over different road conditions including traffic and discourages the driver's bad driving behaviors. Players are able to compete with themselves by comparing performances over the same route on different days or compete with others through the reporting of their rank among all people that have played the game on the same route (see Figure 2). The game level changes over multiple game-play by comparing the player's current performance with prior performances. The percentage rank given at end of each drive reflects the position among all scores gained by other drivers on the same route (means the same start and end points) within the past week.

5. GAME DETAILS AND IMPLEMENTATION

The app collects driving data such as car speed from OBD, accelerometer readings from the smartphone, altitude from smartphone's GPS, and speed limit of the current road from Nokia's maps API service [6]. It analyzes the data in real-time to identify periods of good and bad driving performance. Game rules are designed to motivate the player to drive their vehicle with high performance. Our initial prototype does not account for traffic but we intend to incorporate traffic information and to adjust the thresholds based on heavy and light traffic [6, 7].

In the game's reward system, players receive thumbs-up and thumbs-down, accumulate game score, and earn "virtual money" on each drive. The three types of rewards play different roles in motivating participation. The thumbs-up and thumbs-down counts are shown to players as they drive, since it is the most direct and immediate way of giving feedback of driving performance. The game score is the weighted sum of smooth and hazardous driving incidences that help players understand differences in potential risk of hazardous maneuvers and the difficulty of performing smooth behaviors; thus making the game more realistic. "Virtual money" is accumulated over multiple rounds of game play with the initial balance being 0 for first-time players. It is a long-term measurement that is used to cultivate loyalty to the game.

The game is a HTML5 application that runs inside a Web browser on the smartphone. As the app involves mash-up of data and functionality from the smartphone, the car, and the cloud, HTML5 is a natural programming paradigm for the app. The app accesses driving data from the car's on-board diagnostics (OBD) and smartphone's sensors. The prevalence of sensor-packed smartphones and their co-presence in cars because of their owners make smartphones a natural platform to deliver infotainment apps. Car speed from OBD is accessed through a Javascript API that is implemented as a browser plugin. Altitude and accelerometer data are accessed via local Web services provided by the smartphone. Nokia's Map APIs provide, for example, cloud services for speed limit and traffic information. Finally, the phone is connected to a MirrorLink-enabled head unit via USB. We use MirrorLink [2, 8] technology to deliver the browser-based application running on the smartphone to a car's dashboard. Drivers can leverage the head unit's larger screen and interact directly with the head unit's touchscreen, which is safer and easier to use.

6. SUMMARY AND NEXT STEPS

Our infotainment app uses performance driving and game techniques to entertain drivers on routine drives. Our next steps include extending the game with different persona and features mentioned earlier (e.g., cornering, lane changes, traffic) that form the basis of our overall design. As well, we plan to obtain user feedback to verify our assumptions that: 1) drivers are 'entertained' while playing our game; 2) drivers are not distracted and operate vehicles with more caution when playing our game, and 3) drivers improve on their performance driving skills as a result of playing the game during routine drives.

7. ABOUT THE AUTHORS

Chuan Shi is a Ph.D. student at the University of Minnesota and a research assistant for the GroupLens Research Lab focusing on the design of movie recommendation systems that leverage folksonomy. His research interests include human-computer interaction, mobile interface design and recommender systems. As a 2012 summer intern at Nokia Research – North America Lab, he explored and developed mobile HTML5 automotive apps.

Hae Jin Lee is a Senior Researcher at Nokia Research – North America Lab. She likes to work at the intersection of various creative disciplines including psychology, sociology, art, computer science, and anthropology.

Jason Kurczak is a Mobile Software Engineer at Nokia Research – North America Lab. He likes to explore the intersection of video games, mobile usability, and novel interaction techniques.

Alison Lee is a Research Manager and Principal Scientist at Nokia Research. Her research spans a number of areas within HCI, CSCW, and WWW where she focuses on bridging across technical, design, and behavioral disciplines to create simple, engaging interactions with complex applications. Her current work explores mobile HTML5 apps, services, and technologies critical to mobile HTML5 app discovery and app ecosystem; focusing specifically on the automotive domain.

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Basic Psychological Needs and Enhancing the Driver Experience for Routine Trips

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ABSTRACT

driving experience is proposed that establishes a connection between the driving experience and basic psychological needs. The model represents factors relating to the technical characteristics of the car and the perceived qualities associated with those characteristics. It is argued that by taking this approach, it is possible to obtain handles for generating ideas with the aim of enhancing the driving experience associated with routine trips.

Categories and Subject Descriptors

H.1 MODELS AND PRINCIPLES H1.2 User/Machine Systems, Human Factors

General Terms

Design, Experimentation, Human Factors, Standardization, Theory.

Keywords

User Experience, Automobile User Interface, Theoretical Modeling, Experience Research.

9. INTRODUCTION

For some time I have been thinking about a model capturing factors that affect the driving experience. The model, inspired by models such as Davis (1993), Venkatesh et al. (2003) and Hassenzahl et al. (2000) is shown in Fig. 1. On the left, factors relating to the technical characteristics of the car are shown, capturing the power, equipment, design etc. In the middle, the perceived qualities are shown associated with the technical characteristics. The relation between the technical characteristics and the perceived qualities are moderated by a number of factors such as physical context, social context and driver characteristics. On the right the psychological effects are shown, representing the basic psychological needs which are fulfilled by the driving activity (Reis et al., 2000; Sheldon et al., 2001).

For the time being, the intention is not to validate the model by collecting questionnaire data and fitting the model by statistical techniques such as done by Venkatesh et al. (op. cit.), but rather to use it as a conceptual framework for analysis. Secondly, at the moment the model only captures the experience related to driving. To turn it into a more comprehensive model capturing the driver experience, components should be included for multitasking activities such as made possible by smartphones (emailing, calling etc). Possibly, this can be done by stacking additional layers on top of the model, turning it into a 3D model, and establishing connections between the perceived qualities of the different applications. For instance, the ergonomic quality associated with the driving activity may be influenced by the ergonomic quality of an additional task, because of the cognitive load induced by the two activities and the resulting dual task decrement. Extending the model is beyond the scope of the present paper. Instead, we may use it as a tool for analysis or source of inspiration for thinking about the driver experience, e.g. in the case of routine trips. The productivity of the model will then have to be evaluated by how well it enables us to come up with ideas to enrich the driver experience.

In the current context, the main merit of the model it its emphasis on the psychological effects relating to basic psychological needs. This emphasis paves the way for thinking about how people give meaning to their everyday activities in the context of driving. In general, people engage in certain activities in order to achieve certain goals, and ultimately the motivation for activities is to achieve certain psychological effects, such as building competence, achieving something, actualizing one's own potential, feeling stimulated or pleasant and so on.

Figure 1. Driver Experience Model.

Furthermore, we should keep in mind that activities and goals may be hierarchically related. We drive to work because work enables us to actualize our potential, or to earn money for living. In that sense, the working activity is intended to mediate these basic psychological needs, and the driving is instrumental: it helps us to get to the place where we work. However, the instrumental activity itself provides opportunities for satisfying certain basic psychological needs as well. For instance, while driving to work,

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we aim for autonomy, stimulation or pleasure, and in fact the means for getting to the office is affected by these basic psychological needs. That is, in the way we implement the instrumental activity, again we will make choices that enable us to give meaning to our everyday activities and achieve our basic needs.

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10. DRIVER EXPERIENCE FOR ROUTINE TRIPS

We may assume that the driving activity involved in routine trips provides little opportunity for fulfilling basic needs. The driver knows the route quite well and the skills needed to drive the route are over-trained, so that the trip poses little difficulty. In sum, routine trips offer little opportunity for pursuing basic needs such as competence and stimulation (although it should be kept in mind that decreasing the ergonomic quality may create opportunities for fulfilling the basic need of competence). On the other hand, since in many cases routine trips take place in high traffic density conditions, autonomy is at stake: the desire of other drivers to move efficiently from A to B interferes with the driver's desire to do so him or herself. Autonomy needs to be traded against aggregate efficiency for the collective (known as the social dilemma). Thus, applications that facilitate the driver in dealing with the social dilemma, enhancing his actual autonomy or feeling of autonomy, offer a first opportunity for enhancing the experience associated with routine trips.

Another basic need concerned is pleasure/stimulation. In the context of routine trips, there appears little opportunity to relate pleasure/stimulation to the driving activity. The driving activity is felt as unchallenging, unexciting and boring, so that many drivers engage in other activities while driving, such as listening to music, making phone calls and handling e-mails – with obvious consequences for safety. Using gaming elements, we could explore ways to make routine trips more challenging and satisfy the drivers' need for pleasure/stimulation. In addition, such applications might address the need for building competence and feeling competent. Existing applications for Eco Driving such as Fiat's ecodrive are based on these considerations.

Figure 1. Source: http://raf-112-squadron.org/raf_112_squadron_photos_1941.html.

Identity formation, confirmation and expression are needs that appear relevant to the driving context. Although inventories such as those of Sheldon and Maslow do not mention identity as a separate need, theorists such as Burton (1990) do. Also, it has been argued that identity formation is related to the extent to which the basic needs of competence, autonomy and relatedness are fulfilled (Luyckx et al., 2009), strengthening the relation between identity and other basic needs and putting identity formation, confirmation and expression on the agenda for those who connect the user experience to basic need fulfillment. In the driving context we may apply the notion of identity, and in particular the need to express one's own identity as a handle for idea generation. Employing advanced technology, we could think of using the car as a display allowing people to express identity information (which in fact is already done by conventional technology – see Fig. 2 for a picture from the aviation context); of course we would need to provide a proper definition for the notion of identity.

Pursuing on this and considering the need for expressing oneself, which is so evident in social media, we may apply it to the driving context, not only in connection to expressing one's own identity, but also in connection to expressing more temporary aspects such as mood and emotion, giving rise to concepts such as the Emoticar, which conceives of the car as a display for expressing one's own emotion.

Finally, since routine trips usually take place in a social context (even if we do not always appreciate the presence of other drivers around us), relatedness appears very relevant to the driving situation, offering opportunities for idea generation. Clearly, this is associated with the need for expressing one's own identity (or group membership) such as evident in clothing and expressing oneself in general.

11. CONCLUSION

In this paper, we have established a connection between the driving experience and basic psychological needs, and we have argued that, taking the basic psychological needs as a starting point, we obtain handles for generating ideas for enhancing the driving experience associated with routine trips.

12. ABOUT THE AUTHOR

I was trained as a cognitive psychologist. In recent years my research activities have focused on advanced driver assistance and information systems, taking a user-centred design perspective. In addition, I have broadened my interests to include the emotional and motivational aspects of the user experience as well. In the context of automotive research, I am interested in understanding the driver experience and methodology supporting this research.

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