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Adjunct Proceedings „Posters & Interactive Demos“

Organizers:

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Andreas Riener, 2011-11-28

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Preface

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Welcome Note from the Poster/Demo Chairs

It is with great pleasure that we have the opportunity to present the adjunct proceedings of the Third International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '11, http://auto-ui.org). Building on the success of the previous conferences, this conference is becoming the renowned international forum for the dissemination and exchange of up-to-date scientific information on theoretical and practical areas of Human-Computer Interaction in the context of cars. This year, the poster and interactive demo session is being held on the second day of the conference (December 1st, afternoon) at the ICT&S Center, University of Salzburg. The adjunct proceedings are published on the conference website and are provided on your thumb drive.

Many people have devoted considerable time in reviewing and selecting those pieces of work which will be presented here. The poster and interactive demo program addresses diverse human-computer interaction issues in the context of cars, including new interactive apps, devices, toolkits and metaphor use, research and design process, methodologies, and tools appropriate for this domain, as well as studies that improve our understanding of special populations (e. g., drivers in road rage or drivers with traumatic brain injury). We have embraced all of these topics in the hope to foster a new community which aspires a recurring annual gathering on automotive user interfaces and interactive vehicular applications. In addition, we have combined many of the experiential aspects of the conference such as one minute madness for the poster session, interactive demonstrations, and exhibits. We expect that the poster and interactive demo session will be more alive than ever with these various new attempts.

We encourage you to come to our poster and interactive demo session and have fruitful discussions with researchers and practitioners from all over the world. Don't miss the ever-popular "one minute madness", where all Poster/Demo authors will be lined up for a rapid fire, 60-second opportunity to urge attendees to visit them and learn about their work during the reception. The poster session chair, Albrecht Schmidt, will strictly enforce the one minute time limit for each presentation. We have heard that he has been hard at work devising an effective way to signal the end of a one minute time slot – we'll have to wait until the session to find out what he will choose in the end…

We would like to thank each and every one of you for your valuable contribution towards the success of this conference, especially the poster and interactive demo session, and to wish you a professionally rewarding and socially enjoyable stay in Salzburg. Enjoy the spirit of Salzburg!

Andreas Riener
Myounghoon Jeon

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Part I.

Poster Abstracts

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The use of in vehicle data recorders and self-reported data for evaluating driving behavior of young drivers

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ABSTRACT

This paper aims to evaluate the driving behaviour of young drivers few years after licensure. The evaluation is based on two kinds of data: In Vehicle Data Recorders (IVDR) and Self-Reports (SR). The results show that young drivers clearly perceived themselves as safer drivers than they are according to IVDR. The results also suggest, based on the two approaches, that young driver improved their driving behavior while driving with IVDR. The analysis obtained should be considered as exemplifying the potential of what may be done with these two evaluation approaches.

General Terms

Measurement, Experimentation.

Keywords

In Vehicle Data Recorders, Self-reports, Young drivers,

1. INTRODUCTION

Young drivers in Israel, similar to other places over the globe, are involved in car crashes more than any other age group [1,2]. The definition of a "young driver" in many countries refers to relatively wide age group, e.g., the ages of 17-24 in Israel. This paper aims to evaluate how young drivers in the age of 19-24 drive 3-4 after licensure. The evaluation was done using two tools: In Vehicle Data Recorders (IVDR) technology and Self-reported data (SR). More specifically, we focused on the relationship between these two measurements.

IVDR can be used for unobtrusive recording of driving behaviour under ordinary traffic conditions. This advanced recording equipment is installed in driver's car, tracks all trips made by the vehicle and provides information regarding trip characteristics and safety levels. The manoeuvres detected during driving are classified into major categories of events, e.g., speeding, turn handling, and the quality of performance of the detected manoeuvres is evaluated. Drivers are color-coded according to their safety classification: green (cautious), yellow (moderate) and red (aggressive) [3,4].

SR are very popular tools employed in driver safety research and many studies use it even as a sole source of data. SR has many well recognized advantages, such as its ease of use andthe ability to collect large data sets relatively cheaply but suffers from well known limitations regarding its validity as an indicator of actual behaviour [5].

This paper is based on a study done in Israel as part of the PROLOGUE project conducted within the EU FP7 [6].

2. METHODOLOGY

IVDR systems have been installed in the private cars of the participants, 32 young drivers with 3-4 years of driving experience at average age at the time the study started of 20.5 ± 0.5 years. The participants were recruited from a participants' pool that participated as novice young drivers in a study conducted in Israel few years ago [3]. All trips were monitored in a study period of 8 months. The study period was divided into three stages: the "blind profile" stage which started immediately after the installation, provided no feedback and served as a baseline; the "feedback stage" that followed in which participants received real-time and via the internet feedback; the final "cool-off" stage in which the participants continued to drive with the IVDR but did not receive any feedback. During the "blind profile" and "cool-off" stages participants were asked to fill in specific trip diaries regarding various characteristics of the trips they have taken in the last 48 hours, e.g., date, time, duration, trip purpose, perceived level of trip safety, etc.

3. RESULTS

Table 1 presents general statistics of the trips the participants undertook. These trips are used in the analysis that follows. The SR compiled for specific days

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in the no feedback stages (i.e. the blind profile and the cool-off stages) were compared to the data collected by the IVDR for the same days. The matching was based on the trip date and time that the driver reported.

Table 1. Characteristics of the trips undertaken

	"Blind profile" stage	"Feedback" stage	"Cool-off" stage
No. of trips	1,859	3,050	1,565
Total duration of trips (hrs)	846.2	1179.4	601.1
Trip duration Average (min)	27.3	23.2	23.0
SD of trip duration (min)	22.8	26.1	22.1

The comparison of IVDR data and SR data was done with respect to two factors for the two no-feedback stages: driving exposure and trip safety evaluation. The results show high correlation of driving exposure which was self-reported and data obtained from IVDR. The correlation was 0.96 at the level of individual participants in the "blind profile" stage and 0.90 at the level of individual participants in the "cool-off" stage. We also compare the trip risk classification provided by IVDR to those perceived by SR.

IVDR and SR data provide information regarding each trip safety level: red, yellow, or green. Based on these the overall risk evaluation scores (RES) of each trip have been calculated within an interval ranging from 0 to 1. For the categorization, values up to 0.2 are categorized as low-risk (green), $0.2 \leq RES < 0.5$ indicate intermediate driving (yellow), and values over 0.5 indicate aggressive driving (red). Accordingly, on the aggregate level, in the "blind profile" stage, the average RES obtained from IVDR is 0.465 compared to 0.185 obtained from the SR. In the "cool-off" stage the average RES obtained from IVDR is 0.270 compared to 0.035 obtained from the SR. That is, with respect to the risk levels, there is a significant improvement in the "cool-off" stage. This may indicate that these participants did improve their driving behaviour while driving with IVDR and are aware of that.

The illustration of the comparison of the perceived RES to the RES calculated from the IVDR in the "cool-off" stage per each participant is shown in Figure 1. Trips were matched only for 14 participants. In the figure, the bar for each participant represents his or her average RES based on the IVDR risk levels whilst the bar's colour is coded according to the RES based on self-reported risk levels (green for low, yellow for intermediate and red for high risk). The figure indicates that 6 out of the 14 participants perceived their trips in general as safer than they are according to the IVDR data (e.g. participants with RES of 0.85-0.9 are above the red line and certainly are "red" but perceived themselves as "yellow"), 7 classified themselves similarly to the IVDR and only one self-reported higher risk level compared to the IVDR. The IVDR risk classifications were higher (specifying lower level of safety) than the self-reported, indicating that the drivers perceived the trips they undertook as significantly safer compared to the IVDR evaluation.

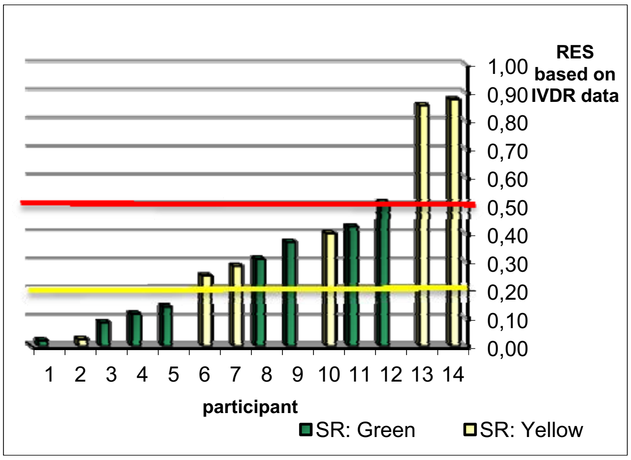

Figure 1. Risk evaluation scores IVDR vs. SR

4. CONCLUSION

The results show that young drivers clearly perceived the trips they undertook all the time as safer than they are according to IVDR data. The young driver improved their driving behavior while driving with IVDR: their risk evaluation score was significantly safer in the final "cool-off" stage compared to the initial "blind profile" stage. However, it is important to take into account that the analyses are based on a small sample of 32 participants, which are by no means representative of young drivers. The paper also points out the potential of using these two approaches for evaluating driving behavior. However, more effort should be put on the manner in which these data are generated and compared.

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Information Extraction from the World Wide Web Using a Speech Interface

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ABSTRACT

Due to the mobile internet revolution, people tend to browse the World Wide Web while driving their car which puts the driver's safety at risk. Therefore, a speech interface to the Web integrated in the car's head unit needs to be developed. In this paper, we present a speech dialog system which enables the user to extract topic related information from web sites with *unknown* page structures. One challenge is to extract and understand the requested information from the web site which is achieved by parsing the HTML code against a predefined semantic net where special topics (e.g. "weather") are modelled. The extracted information is the basis for the generic speech dialog which is designed in an intuitive and driver-convenient way in order to not distract the user.

Categories and Subject Descriptors

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

1. MOTIVATION

The arrival of smartphones has shaped new expectations towards mobile devices: Using mobile internet the user is able to get instant access to content-relevant information, infotainment systems, and services, anytime and anywhere. The success of smartphones also significantly impacts automotive systems. However, since for safety reasons smartphones and similar existing technologies cannot be used while driving, cars are the only place where accessing web sites on a regular basis is not possible, yet. Reports from the U.S. Department of Transportation[4] revealed that 20 percent of injury crashes involved distracted driving. While driving a vehicle browsing the Web by using the car's head unit would distract the user and puts the drivers' safety at risk. Therefore, when bringing Internet to the car a speech-based interface which provides a driver-convenient, audible representation of the content needs to be developed. Currently, browsing the World Wide Web is only achieved by using haptic input modalities and a visual browser representation.

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However, in a driving environment this user interface is not feasible. Therefore, it is crucial to develop an intelligent web scraping algorithm which transforms semi-structured Web content in a representation accessible by the speech dialog. Attempts to access the World Wide Web by speech have been made in different ways. Poon et al.[5], amongst others, have introduced voice browsers which is not applicable in the automotive environment due to high cognitive load and time consumption. In the SmartWeb project[1] the user can ask questions about the Soccer World Cup and the system provides answers retrieved from amongst others, a knowledge base containing information extracted from the FIFA web site. Nevertheless, this algorithm is only able to extract information from dedicated web sites with known web page structures.

In this paper, we present a speech dialog system (SDS) designed in a driver convenient way which allows the user to retrieve topic related information from the World Wide Web which is available in an HTML structure. The core component of the proposed approach is an ontology which models the mentioned topics. The speech dialog is modelled according to the ontology and the information extraction (IE) component parses HTML code against the predefined semantic net. In this way, information from web sites with *unknown* web page structures can be extracted, understood and accessed by speech.

2. INFORMATION EXTRACTION FROM SEMI-STRUCTURED WEB SITES

Previous approaches to IE from web sites focus on the web page and try to extract relevant information only from the corresponding HTML DOM tree. In our approach, we first define an ontology to a certain topic and use topic-related web sites as our source to find matching information. The ontology the web site's content is mapped on is defined in KL-ONE[2] because of its simplicity and sufficient modeling abilities. The IE and the semantic analysis of a web site is illustrated in Figure 1 and explained in the following.

First, the HTML parser analyzes the web site and generates a preliminary internal graph representation. Hereby, dynamic contents are processed, embedded frames are loaded and referenced web pages are taken into consideration.

In the second step, the text parser analyzes the textual content. By applying topic-oriented grammar definitions, the text parser generates initial concept hypotheses of the semantic model for each textual content.

Since the following matching algorithm is computationally intensive, the current cyclic graph needs to be transformed

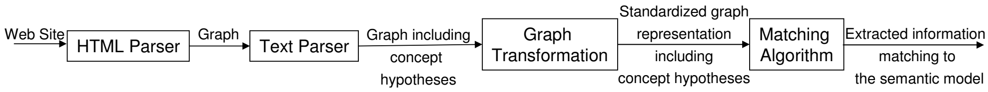

Figure 1: Overview of the web scraping algorithm.

into a simple and standardized internal representation to accelerate the matching process. Structural, context sensitive and HTML-tag specific rules are applied to simplify the graph.

Finally, the matching algorithm maps the graph structure onto the concepts of the predefined semantic model. The result of the matching algorithm is a set of instances containing extracted information from the web site. The result is available in the structure of the semantic model and therefore, can be presented by a speech dialog which has been modelled explicitly for the respective topic.

3. GENERIC SPEECH DIALOG

The generic speech dialog is adapted to the ontology and modelled for each topic explicitly. To reduce the driver distraction, the dialog has to be designed in an intuitive and natural manner. The Daimler speech dialog control follows a user adaptive dialog strategy without having a globally fixed "plan" of the dialog flow. Here, the dialog is modelled as a hierarchy of sub-tasks including roles which can trigger a system reaction if the corresponding user input is given. Thus, the dialog becomes very flexible and adapts to the user's input [3]. Since XML is well structurable and straight forward to parse, a particular XML specification is used to model the dialogs and to define the integration of semantic contents into the dialog specification.

The user is able to input multiple information at once. Furthermore, by designing flexible grammars, many ways to input data are possible. These features lead to a fast and natural interaction. By keyphrase spotting, the user's input is understood and mapped onto the corresponding concept in the predefined ontology.

4. EVALUATION

For the first evaluation, a system prototype has been developed for German web sites and the topic "weather". Since each weather web site's layout and contents differ, several weather web sites were analyzed to establish the semantic model and the parser grammar. A weather standard format (including location, forecast for 3 days, weather descriptions, temperature values, precipitation and wind) has been defined by us for evaluation. Furthermore, different weights to emphasize the importance of the information have been introduced (e.g. temperature values are considered more important than wind information).

The first five google hits for "wetter" (German for "weather") were used to evaluate the performance of the IE algorithm. The result of the web scraping algorithm is the hierarchically highest concept. The coverage of the extracted data w.r.t. the standard weather definition has been computed. The results are illustrated in Table 1.

The results show that not every web site provides the required data w.r.t. the standard weather definition. Some web sites do not offer information for each time of day or the detailed precipitation or wind information is missing.

The algorithm succeeds in four out of five web sites to extract more than 50% of the available data and 63% in average. All the information could be extracted from web site no.③ but from web site no.④ no data could be extracted.

		Available data w.r.t. the standard weather definition	Extracted data w.r.t. available data
①	www.wetter.com	100%	91%
②	www.wetter.de	67%	53%
③	www.wetteronline.de	81%	100%
④	www.wetter.net	86%	0%
⑤	www.donnerwetter.de	65%	72%

Table 1: *Results of the evaluation.*

In the HTML code of web site no.④, the content is distributed into several tables. Currently, the algorithm is not able to combine tables and therefore, cannot interpret the presented information. It often occurs that web sites provide images without alternative texts (e.g. web site no.②). With the current implementation of the system, these contents could not be extracted. By extending the parser grammar and the transformation rules, the missing information can be extracted.

The speech dialogue presents the user the information which the web site provides. However, if the algorithm fails in extracting all the information, or if a web site does not provide the necessary information, the dialog manager can trigger the IE component to extract the missing information from another web site. Rules for merging the information will be implemented which will overcome the lack of extracted information presented in Table 1.

5. CONCLUSIONS

In this paper, we presented an SDS which allows the user to retrieve topic related information from the World Wide Web which is available in an HTML structure. By parsing the DOM tree against a predefined semantic net, the requested information can be extracted from *unknown* web sites. A generic and intuitive speech dialog has been designed which is adapted to the semantic net. The results are promising and open the possibility for future research and improvements of the SDS. In future, we will improve the web scraping algorithm and evaluate the system for other topics to demonstrate the universality and versatility of this approach.

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IVAT (In-Vehicle Assistive Technology): Multimodal Design Issues for TBI Drivers

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ABSTRACT
Individuals who have survived a traumatic brain injury (TBI) can experience a variety of sequelae that may limit their ability to drive. Despite great safety risks, the majority of individuals who return to driving following a TBI do so without ever undergoing formal evaluation [1]. Assistive technology can be leveraged in the context of driving to facilitate autonomy for this population. Multisensory integration is known to have facilitatory capabilities at the neural, cognitive, and behavioral levels. We have the opportunity to address the needs of this user group by utilizing in-vehicle multimodal interfaces. The aim of our in-vehicle assistive technology (IVAT) project is to increase driver safety by first considering individual abilities and limitations and then tailoring support to meet those specific needs. We have developed an initial iteration of such a system through a user-centered design process with both rehabilitative driving evaluators and drivers with TBI. Our goal is to enable individuals to overcome limitations and regain some independence by driving after injury. The purpose of the current paper is to outline the findings from our needs assessment for this population of drivers and highlight the critical concepts drawn from multimodal perception theory that could be integrated into addressing the needs of these drivers.

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

General Terms
Performance, Design, Human Factors

Keywords
Driving, Cognitive Limitations, TBI, Assistive Technology, Human Factors

1. INTRODUCTION
Millions of people incur, and then strive to recover from, traumatic brain injuries (TBI) each year. Following extensive rehabilitation, they are often able to reintegrate into daily life. The ability to drive a car unsupervised is often a critical factor in regaining independence [2]. Unfortunately, many TBI survivors (and indeed people with various disabilities) have residual perceptual, cognitive, motor, or affect-control deficits that impact their ability to drive, among other activities. Much of what is understood about normal perception during driving has been derived from unimodal studies, as these were traditionally the focus within perception research. Though unimodal literature has contributed greatly to our understanding, its overemphasis has left critical gaps in perceptual theory [3]. Interactions within the driving environment are almost never truly unimodal. Though the sensory channels are differentiated, the experience is not of a fragmented collection of sensations, but rather an integrated concept of the external world. Sensory information from multiple modalities must be integrated online despite vast differences in initial cognitive encoding [3]. Audiovisual integration research has direct implications for modern display design and can be particularly useful in the context of driving, a task that heavily taxes the visual modality.

The IVAT (In-Vehicle Assistive Technology) system is a framework for developing a range of multimodal assistive applications, each tuned to the particular needs of the individual. The IVAT research team is particularly well suited for tackling issues with driving after TBI. The Shepherd Center, a private, not-for-profit hospital specializing in research and rehabilitation for people with spinal cord and brain injury, is recognized as one of the U.S.'s leading rehabilitation centers. The Sonification Laboratory at Georgia Tech focuses on the development and evaluation of auditory and multimodal interfaces, paying particular attention to Human Factors in the display of information in complex task environments. The Georgia Tech School of Psychology's Driving Simulator Facility houses a National Advanced Driving Simulator (NADS) MiniSim featuring full field-of-view immersive environments (see Figure 1). In the current research, an in-vehicle PC is utilized with Centrafuse™ Application Integration Framework software that merges connected car technology and IVAT within a multimodal in-dash touch screen interface. IVAT utilizes positive reinforcement to promote skills and behaviors known to increase driver safety.

Figure 1. IVAT in-dash display

2. Driving After Traumatic Brain Injury

The level and type of limitations resulting from TBI depend on characteristics of the injury: severity, mechanism, and location. The most common causes of TBI include violence, transportation accidents, construction mishaps, and sports injuries [4]. Driving after TBI has been identified as a critical component of achieving autonomy and reintegration into the mainstream community [2]. Despite great potential risks, the percentage of individuals who return to driving after TBI is believed to be as high as 60% [1] of the 2 million new cases in the U.S. each year [5]. Less than half of these (37%) ever receive professional driving evaluation [1]. Cognitive, behavioral, and physical sequelae commonly associated with TBI that have been shown to have negative effects on safe driving include: information processing speed, psychomotor speed, visuospatial ability, and executive function including meta-awareness [6]. Assessments of these key symptoms have been shown to validly predict safe-driving ability after brain injury [6][7]. Training that focuses on visual scanning, spatial perception, attention focusing skills, and problem solving is believed to significantly improve driver awareness of shortcomings and driving abilities (anosognosia) [6].

During our needs assessment process, an over-arching challenge that emerged was the propensity for individuals with TBI to forget that they are driving mid-task. This stems from meta-awareness deficits and can be observed by a 'glazed over' look and the onset of defensive driving practice neglect. IVATs initial design was inspired by the Shepherd Center's Electronic Driving Coach (EDC) device, which was specifically designed to address this need by keeping the individual engaged in the driving task [8]. To achieve this, the driver is trained to register each time they find themselves practicing a defensive driving behavior (e.g., mirror scanning, active space maintenance, and speed checking). Once the driver's input is registered, the system speaks a positively reinforcing message related to the specific defensive driving practice. For example, "Great job checking your speed! It's easy to accidentally drive faster than the posted limit." Additionally, IVAT is programmed with a time-out function that automatically prompts the driver if he or she has not registered any defensive driving behaviors within a specified length of time. Focus groups with users up to a year after EDC implementation reveal that they find themselves better able to remain engaged in the driving task and have seen a decrease in driving-related issues such as traffic violations [9]. While we aim to continue system improvements to further address executive functioning deficit, we now wish to expand functionality to address other identified classes of cognitive limitations such as information processing speed, psychomotor speed, and visuospatial ability. We believe that the solution to addressing these needs lies within multimodal perception theory.

3. Multimodal Performance Facilitation

Enhanced performance in the presence of bimodal versus unimodal stimuli is widely reported [3]. Generally, it is thought that it is the redundancy of multimodal stimuli that leads to performance enhancement (i.e., *target redundancy effect*). Facilitatory performance effects include faster reaction time, increased accuracy, and decreased detection thresholds [10][11]. Single-cell recordings of multisensory superior colliculus (SC) neurons have revealed that neural response to multimodal stimuli is greater than that to unimodal stimuli in a manner that is sometimes superadditive (i.e., greater than the sum of unimodal inputs alone) [12]. The degree of multimodal neural enhancement increases with 1) the degree of spatial overlap due to stimuli falling within increasingly aligned receptive field excitatory regions and 2) the degree of perceived synchrony of multimodal inputs due to maximal overlap in respective periods of peak neural activity [13]. The implications for multimodal displays are such that the wrong placement of signals in space or time can have detrimental consequences. Outside spatial and temporal multisensory integration boundaries lies an inhibitory region where perceptual processes may act to suppress neural response, thus degrading signals in order to disambiguate distinct external events [12]. The ability of multimodal stimulation to facilitate performance has promising implications for individuals who drive following TBI. However, defining the spatiotemporal boundaries for this population is the critical next step for expanding IVAT system functionality.

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ENGIN (Exploring Next Generation IN-vehicle INterfaces): Drawing a New Conceptual Framework through Iterative Participatory Processes

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ABSTRACT
This paper presents an initial stage of the ENGIN (Exploring Next Generation IN-vehicle INterfaces) project. In order to create next generation in-vehicle user interfaces, iterative participatory processes were used: brainstorming, drawing affinity diagrams, conducting focus groups, and hosting expert panel sessions. Through these various inputs, we tried to balance among technology trends and feasibility, users' needs, and experts' considerations. This explorative study approach is expected to provide a blueprint of the automotive user interfaces in the near future and to guide researchers in academia and industry.

Categories and Subject Descriptors
H.5.2. **[Information Interfaces and Presentation (e.g., HCI)]**: User Interfaces – interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design

General Terms
Design, Human Factors

Keywords
Next Generation In-vehicle Interfaces, Participatory Design

1. INTRODUCTION
During the last century, cars were merely thought of as a way of transportation or delivery. Currently, as cars are becoming more advanced machines, the design of in-vehicle technologies is more than simply the design of a space for the driving task alone. Often, cars can also be referred to as "offices-on-the-move" [6] or "personal communication centers" [5] with more complex functions. However, because academic research has focused on performance and safety issues, [e.g., 2, 3], it is hard to find literature that provides a perspective on the integration of upcoming new features (exceptions such as [1, 4]). The present study introduces iterative participatory processes on drawing a conceptual framework for the next generation in-vehicle interfaces. Most of the addressed concepts and technologies were ongoing research in 2010, but some of them have since appeared on the market.

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2. CONCEPT-DRAWING PROCEDURE
We adopted various methodologies with multiple populations in order to obtain balanced data among technology trends and feasibility, users' wants and needs, and human factors experts' guidelines and considerations. The overall procedure was as follows: benchmarking – brainstorming sessions with drivers – affinity diagram session – human factors expert panel session 1 – focus group sessions with drivers – human factors expert panel session 2 – prototyping. Among these, we highlighted only a few sessions here.

2.1 Brainstorming & Affinity Diagram Sessions
First of all, we investigated current products and manuals in industry (e.g., Tomtom, Garmin, Benz, BMW, Ford, etc) as well as recent research in academia (e.g., journals and conference proceedings such as Automotive UI, Driver Distraction, Driving Assessment Conference, MIAA Workshop, Human Factors, CHI, etc). Moreover, researchers had their own brainstorming sessions with their own colleagues. In addition to benchmarking results and separate brainstorming results, we conducted an integrated brainstorming and affinity diagram session. In this session, four researchers brought up 10 ideas with titles and descriptions. At first, one researcher announced the title of the idea and the remaining participants wrote down their own new ideas on the post-it inspired by the title. After that, the researcher explained his own idea in full. In this way, we obtained more than 100 ideas at the end of this session. All the ideas on the post-its were classified according to their contents (Figure 1 (b)). We used top-down and bottom-up categorizations (e.g., top-down headings from general HCI trends, Automotive UI trends, and some conference session names and bottom-up categories from our ideas). After iterative discussions and classifications, we created five categories with a focus on the relation between a driver (referred to "me") and a car, which is a unique story-telling about the future in-vehicle technologies (Figure 2): 1) Extended Body, 2) Augmented Cognition, 3) Link Me & Mine (co-driver, friends, and family), 4) Aware of Me, Learn about Me & Meaningfully Use My Info, and 5) Think about My Environment.

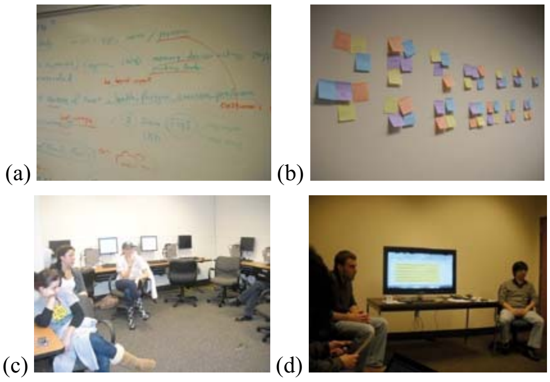

Figure 1. Concept-drawing processes included (a) Brainstorming, (b) Affinity Diagram (c) Focus Groups, and (d) H/F Expert Sessions.

2.2 Focus Group Sessions

Through the Brainstorming and Affinity Diagram Session, we developed 21 detailed concepts within the five categories mentioned in the previous section. With these concepts, we conducted five focus group 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 we prepared: purpose of using their car, necessary information while driving, bad experiences in 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 21 concepts in a low-fidelity prototype (Microsoft Power Point) with detailed usage scenarios while gathering participants' comments on each idea. Finally, participants provided their preference on each concept selecting their 'top three choices' and using a 'seven-point Likert Scale rating'. Based on participants' choices and ratings, we attained top five concepts as follows:

- **Free Parking Spot/ Parked Car Finder** (Best choice N = 9/18, Rating score: 6/7): Drivers get information from the central server to locate vacant parking spots and guidance to navigate to them.
- **Drive-by-Payments** (7/18, 5.4/7): Drivers can pay for fast food, meter parking, gas, and more through their vehicle's interface.
- **Fatigue Meter** (6/18, 5.05/7): Drivers' fatigue state is kept track of and some adaptive user interfaces are provided.
- **HomeNet** (5/18, 5.5/7): Drivers monitor, control, and manage their home appliances in car.
- **Temperature / Proximity Sensor** (5/18, 6.1/7): In-vehicle interfaces alert the driver to external temperature outside as well as alerting about near or approaching objects.

Other highly ranked concepts included 'Entertainment on Demand' (5.6), 'Global Profile of Driver' (direct custom infomercial intended to suit drivers' situations) (5.16), 'Route Buddy' (the in-vehicle agent remembers the drivers' data and suggests information) (5.05), 'Steering Wheel Alerts' (5), 'Green Speedometer' (the speedometer indicates an economical driving), and 'Peripheral Auditory Display' (4.94).

2.3 Expert Panel Sessions

We conducted two expert panel sessions: one was administered after the Affinity Diagram Session and another was done after the Focus Group Sessions. In total, five Human Factors or HCI exerts (H/F & HCI experience > 5 years; two holding PhD and three holding MS) participated in sessions. Similarly to the FG sessions, researchers demonstrated 21 concepts and experts were allowed to discuss, comment, and advise on each concept through the session. Their main concerns including safety, security, privacy, and allocation of modalities enabled us to define our ideas more concretely.

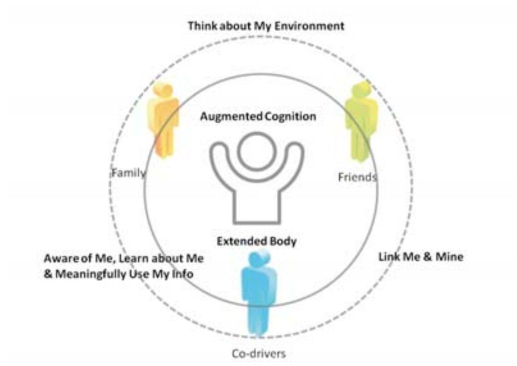

Figure 2. A new conceptual framework for the future in-vehicle technologies with a focus on a the relations between technologies and a driver (referred to "me")

3. CONCLUSION & FUTURE WORKS

This paper presented iterative processes to create a new framework and detailed concepts of the next generation in-vehicle user interfaces. Via multiple iterations of the sessions including drivers, researchers, and experts, we attained feasible idea sets and the results are expected to provide a new perspective on automotive user interfaces. Although several concepts obtained good feedback from drivers and experts, it is still necessary to identify the remaining detailed user experience issues. Our next step is to implement some of these concepts as higher-fidelity prototypes and validate them in a driving context.

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The HMISL language for modeling HMI product lines

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ABSTRACT

This paper introduces the HMISL language which serves to model the behavioral logic of HMI product lines. HMISL models are structured into separate modules that can be reused for creating the software of different HMI variants by means of code generation. The language is designed to be applied along with different tools for GUI modeling available on the market.

Categories and Subject Descriptors

D.3.2 [**Programming Languages**]: Language Classifications – *specialized application languages, very high-level languages*; D.3.3 [**Programming Languages**]: Language Constructs and Features; D.2.2 [**Software Engineering**]: Design Tools and Techniques – *user interfaces;* D.2.13 [**Software**]: Reusable Software – *Domain Engineering;* H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Graphical user interfaces (GUI);* D.2.6 [**Software Engineering**]: Programming Environments – *Graphical environments*;

Keywords

HMI, Automotive, DSL, model-driven software development, domain-specific languages, HMISL, code generation

1. MODEL-DRIVEN HMI DEVELOPMENT

Model-driven software development promotes to automatically generate software based on models that provide all necessary information in a formal manner. There are models designed for code generation of HMI software that come with different level of abstraction and formalism. Most of them are focusing the structural parts and in particular the layout of the GUI. The dynamic behavior such as the dialogue flow is often modeled using Statecharts [1].

Choosing behavior models with semiformal notations and higher levels of abstraction can be beneficial in earlier project phases. However, for the generation of the final HMI software such abstract models are unsuitable. Because their level of detail is too low and they lack expressiveness to provide the code generators with all necessary information the generated code need to be adapted or complemented manually. Furthermore, using pure Statecharts is more complex than conventional programming languages for modeling certain parts of the HMI behavior such as algorithmic computations and string formatting. For this reason, these parts of the HMI software are not developed in a model-driven way but are coded manually.

1.1 Drawbacks

Applying model-driven approaches together with traditional software development for creating the HMI software gives rise to several integration problems. Integrating the generated software and the parts that were coded manually can call for designs with larger code size or lower runtime performance. It may be necessary, for instance, to introduce additional interfaces or layers in order to ensure the referential integrity of the overall software.

Because the usage of highly-specialized HMI modeling tools requires different qualifications than conventional software development different staff will be assigned to these jobs. Because no vertical development is possible extensive communication efforts is required during HMI implementation. In addition to that bug fixing becomes a very complex task because generated code and manually written code as well as models have to be taken into account and it is necessary to understand how they interact.

1.2 Bridging conventional and model-driven software development by hybrid models

The goal of this work is to overcome the aforementioned problems of model-driven HMI development. In accordance with the idea of Gröninger [2], the approach is based on combining high-level concepts like state machines and a programming language into a textual domain-specific modeling language (DSL) called HMISL [3]. While we started with using LUA as the embedded programming language we later changed to a minimalistic Java dialect in order to take advantage of static typing. The HMISL allows expressing the complete behavior of the HMI in a single formal model. This enables vertical development, semantically rich checks and full code generation of the final HMI software. In contrast to other textual notations like SCXML [4] we decided to use a formal notation that is not XML-based. This allowed achieving a smoother integration of the programming language as well as a clearer and more compact syntax because the one of the embedded programming language did not need to be adapted to the restrictions of XML. For instance, no double escaping of reserved characters is necessary (Listing 1, Listing 2).

```
<state id="wetter_main_page">
    <onexit>
        <assign name="has_target" expr="true"/>
        <if cond="car.destLat eq 0 and car.destLon eq 0">
            <assign name="has_target" expr="false"/>
        </if>
    </onexit>
    <transition event="event.userinput"
        cond="_eventdata.keycode eq '&gt;'"
        next="wetter_main_page2" />
</state>
```

Listing 1 – Example Code in SCXML

```
state weather_main_page {
    on EXIT then {
        hasTarget = true;
        if (CarDestLat==0 && CarDestLon==0) {
            hasTarget = false;
        }
    }
    on userinput(keycode) [keycode==">"] then
        goto wetter_main_page2;
}
```

Listing 2 – Equivalent Code in HMISL

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2. HMI PRODUCT-LINES

Current model-driven software development approaches focus on single products. However, in automotive industry it is common to develop large numbers of different HMI variants that have to be released in quick succession. Because these HMI variants share large commonalities, there is reuse potential that cannot be tapped. Future modeling solutions have to meet the requirements of product lines by enabling to build assets reusable for multiple products with little effort.

The main reasons of variability in automotive HMIs are the need for brand- or product-specific visual designs, different feature sets and adaptations to the culture of the target market such as translation. For each one of these the HMISL offers a specific variability concept. The basic idea is to let all models contribute to a library of assets (Domain Engineering) that can be used to derive different product variants by configuring code generation (Application Engineering) (Figure 1).

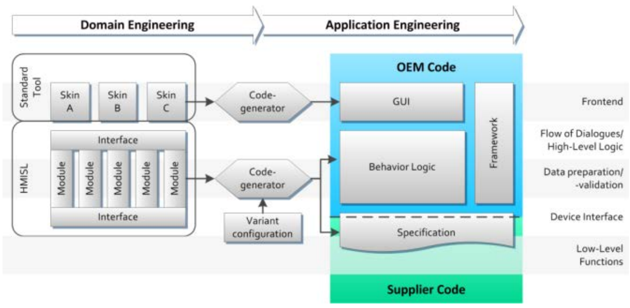

Figure 1 – Overview of structure and usage of HMISL

All logic in HMISL is structured into reusable modules that explicitly define data and events they offer to other modules or expect to be defined elsewhere. A variant configuration needs to select a set of modules from the asset library in a way that all data and events required from its modules are provided by other modules. Furthermore, each module can provide parameters that can be used for its variant-specific configuration. All country- or culture-specific data used in the modules can be extracted to separate configuration-sets called translation that are also held in the asset base. In the variant configuration the translations for its modules are picked from the asset base depending on the requirements of the target market.

The behavior logic mediates between the GUI and the platform services provided by lower software layers. Because of that, two special kinds of modules are required that define interfaces between the HMI behavior logic and these external software parts. The interfaces to the lower level software consist of a detailed specification of the required functionality [5] and describe how this is mapped to events and data used in the behavior modules. The purpose of the interface to the GUI is to make its elements become accessible to other modules without knowing about the concrete visual design or the used technology. The GUI interface contains placeholders for each element that is controlled by the behavior logic such as animations, screens, and widgets. Furthermore, all user interactions that trigger reactions of the behavior logic are mapped to events. The concept of GUI interfaces enables to use the same logic modules with different visual designs which can be created in separate tools chosen depending on the project specific requirements. As a part of the variant configuration a specific visual design (skin) need to be selected that matches the GUI interfaces used by the chosen modules. The code generator then creates the code required to weave both parts together.

3. TOOLING

Because a powerful tooling is crucial for the efficient usage of a modeling language we developed an Eclipse-based workbench for the HMISL language. Its editors offer convenience features known from popular programming IDEs such as code completion, syntax highlighting and connectors to revision control system.

The HMISL uses a textual notation. However, a graphical visualization is valuable when discussing with non-technical staff. This is why the editor tool can generate such visualization and keeps them up-to-date when modifying the textual models. Different visualizations are available showing the state and data flow in the application at various abstraction levels (Figure 2).

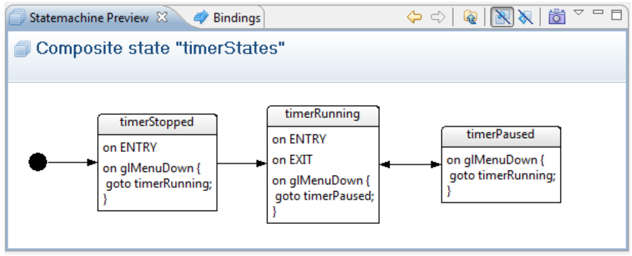

Figure 2 – Generated visualization

4. SUMMARY

Current research in model-driven HMI development focuses on modeling its static part such as the GUI layout. Little is known about modeling the behavior logic of HMI product lines which is addressed by the HMISL language. This language introduces different variability mechanisms that allow deriving HMI variants in an efficient manner. The HMISL combines high-level modeling concepts like state machines with a low-level programming language in order to enable creating models ready for code generation of the complete HMI software. A textual notation is used for editing the models that is not XML. To support discussions with stakeholders corresponding graphical visualization are created on-the-fly.

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Designing a Spatial Haptic Cue-based Navigation System

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ABSTRACT
We have developed a haptic cue-based navigation system that helps a driver find important traffic signs and obstacles in cognitive overload situations. We conducted a visual search experiment using a flicker paradigm to evaluate the effectiveness of the system. The two independent variables used in the experiment were cue validity (valid vs. invalid vs. no-cue) and level of cognitive load (high vs. low). A haptic facilitation effect was found for visual tasks; the response time was shorter when haptic cues were consistent with the location of visual targets (*valid cue*) than when haptic cues were not (*invalid cue*) or when no haptic cues were presented (*no-cue*). In addition, this crossmodal facilitation effect of haptic cues was found in both levels of cognitive load. This result strongly implies the development of a driving navigation system with spatial haptic cues for various cognitive load situations.

Categories and Subject Descriptors
H5.2. User Interfaces: Evaluation, Haptic I/O.

General Terms
Experimentation, Human Factors.

Keywords
Driving navigation system design, haptic interface, vibrotactile, cognitive load, flicker paradigm

1. INTRODUCTION
Current navigation systems usually provide visual and auditory guidance. However, there are some visual and auditory obstacles that prevent a driver from acquiring driving related information from a navigation aid. Haptic cues as an alternative modality to this highly cognitive overloaded situation was considered in this study. Haptic cues can be helpful while driving because they do not interfere with other modalities. In addition, there is evidence of a crossmodal facilitation effect of spatial haptic cues on visual tasks [3, 5]. Therefore we designed a novel navigation aid which exploits vibrotactile cues to represent spatial locations in visual search tasks and evaluated the proposed system under various conditions.

2. SYSTEM DESIGN
We have developed a haptic cue-based navigation system using vibrotactile signals to present haptic spatial information during driving. The haptic interface was mounted on the back of a chair because torso is considered to be suitable for rendering spatial information [1].

The haptic navigation system in this study consisted of a tactor array, a controller board and a host computer. The tactor array included 5-by-5 vibration motors. Each vibration motor was located on the latex rubber which reduces the transmission of vibration from a tactor to others. Five tactors on the top and five tactors on the bottom of the tactor array were used to provide directional information for visual tasks: lower right, lower left, upper left and upper right. Tactors were vibrating one after another to indicate four different directions so that participants could easily perceive directional flows of vibration on their backs. The host computer transmitted information about the direction and timing of haptic cues to the controller board, and the controller board drove the tactor array based on the received information.

3. SYSTEM EVALUATION

We conducted a visual search experiment using a flicker paradigm to evaluate the usefulness of the system.

Participants. Sixteen university students (Males: 7, Females: 9) volunteered to participate. Their mean age was 22.4 (SD= 1.7). They did not have any visual or haptic health problems.

Design. The two independent variables used in the experiment were validity (valid vs. invalid vs. no-cue) and cognitive load (high vs. low). As to the validity factor, a vibrotactile cue was defined as *valid* if the directional flow of the vibrating tactor indicated the quadrant where the changing object was presented; a vibrotactile cue was defined as *invalid* otherwise; *no cue* was without any vibrotactile cues presented. The occurrence ratio between the valid haptic cues and invalid haptic cues was 3 to 1 throughout the entire experiment. The visual cognitive load factor had the two levels of depending on visual complexity. Visual scenes with highly dense objects were defined as a *high* overload condition, because visual search tasks with those scenes were expected to be difficult [4]. Visual scenes were otherwise defined as a *low* level of cognition overload condition. The level of cognitive load of each visual scene was examined in the pilot test. The occurrence ratio between the high and low cognitive load conditions was the same throughout the experiment.

Procedure. First, they conducted a practice session where they could become aware of vibrations and clearly identify the direction of vibrations presented on their back. The visual change-detection task consisting of two blocks of 28 trials conducted after the practice session. For each trial, a fixation point was presented in the center of the screen at the beginning, and then a vibrotactile cue was rendered. After a short pause, the visual change-detection task began. During the task, an original photograph and a modified photograph which contained only one different object were repeatedly alternated and presented to participants. We asked participants to find and locate changing objects on the host computer's screen as quickly as possible, and their response times were recorded for analysis. Visual stimuli were presented until participants found changing element.

4. RESULT

Response times for each condition were recorded during the experiment and used as dependent variables in analysis. A two-way repeated-measure ANOVA with validity (valid vs. invalid vs. no-cue) and cognitive load (high vs. low) as within-subjects factors was carried out.

The analysis showed that the main effect of validity was statistically significant ($F(2,30)=42.54$, $p<0.001$). The result indicated the usefulness of the vibrotactile cue for the visual search task. The main effect of cognitive load was also significant ($F(1,15)=90.20$, $p<0.001$). Response times were significantly shorter in the low cognitive load condition than in the high cognitive load condition. There was no significant interaction effect between validity and cognitive load.

Pairwise comparisons for validity showed that the response times in the valid cue condition were significantly shorter than in the invalid cue condition and also in the no-cue condition ($p<0.001$). The analysis also showed that the vibrotactile cues for conveying spatial information were useful for both levels of visual cognitive loads.

5. CONCLUSION

In this research, we designed and evaluated the haptic cue-based driving navigation system which uses vibrotactile cues to present spatial locations in the visual task. The result showed the efficiency of haptic cues in a visual search task while driving.

Valid haptic cues facilitated the participants' performance, elicited shorter response times in visual search tasks than invalid and no haptic cues. This crossmodal facilitation was found in both high and low cognitive load conditions. In other words, the vibrotactile cues for spatial information were efficient for any level of visual cognitive loads in the driving situation. The result of this research implies the development of haptic cue-based driving navigation system.

For future work, more research on the crossmodal facilitation of haptic cues under various visual tasks is necessary. In addition, the crossmodal interaction of haptic and auditory or haptic, visual and auditory should be dealt to provide a guidance in designing of future navigation systems.

6. ACKNOWLEDGMENTS

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Investigating the Usage of Multifunctional Rotary Knobs in the Center Stack with a Contextual Inquiry

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ABSTRACT
In this paper, we describe the setup and selected results of an in-situ study, aiming at investigating the usage of In-Vehicle Information Systems (IVIS) in the car. Thereby we focus on three commercial systems that combine a multifunctional rotary knob and an LCD in the center stack (Audi RNS-E, Audi MMI, BMW iDrive). In order to investigate tertiary tasks with a special focus on context and user experience factors we performed a Contextual Inquiry. More than 15 different tasks were identified concerning the operation of the radio, the navigation system and the telephone. Our results demonstrate that using an IVIS was especially distracting in rapidly changing situations. Comfort and safety, which are relevant user experience factors in this study, occurred mainly in connection with the operation of the navigation system.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies, theory and methods*

General Terms
Human Factors

Keywords
HMI, contextual inquiry, automotive, study, input modality, IVIS

1. INTRODUCTION
Modern cars provide a multitude of input and output modalities to assist and support the driver regarding primary, secondary and tertiary tasks. Tönnis et al. [5] describe primary tasks as maneuvering the vehicle, secondary tasks as mandatory functions to increase safety (e.g. setting turning signals) and tertiary tasks covering entertainment and information functionality. Especially for tertiary devices the automotive industry has chosen different interaction modalities. Recently a shift towards multifunctional devices can be observed [5]. They allow centralized access to all tertiary functions, while providing a high level of ergonomics, e.g., Audi’s Multi Media Interface (MMI) (www.audi.com) and BMW’s iDrive (www.bmw.com). The systems provide one central controller (rotary knob) positioned in the horizontal center stack.

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In order to investigate the actual usage of In-Vehicle Information Systems (IVIS) we performed an adapted version of Beyer and Hotzblatt’s [1] Contextual Inquiry (CI). Three main research questions were defined:

- What kind of tasks is performed with the multifunctional rotary knob and how do participants use the system in order to carry out these tasks? (RQ1)
- To what extent do interactions with the system have an influence on the primary task of driving? (RQ2)
- What are the users’ experiences and requirements towards the system? (RQ3)

2. BACKGROUND AND RELATED WORK
So far, only a few qualitative in-situ studies have been conducted within the automotive area. Esbjörnsson et al. [2] conducted an ethnographic study in order to investigate naturally occurring mobile phone use in traffic. Their results show how drivers adapt driving behavior and mobile phone usage to match each other. Hjälmdahl and Várhelyi [4] indicate that in-car observation with human observers in the car is a reliable and valid method to study driver behavior with specific focus on traffic safety. Gellatly et al. [3] adopted the contextual design process, aiming to investigate driver’s interactions with entertainment, communication, navigation and information systems in their vehicles. The authors identified a row of barriers in and around the car, which distract the driver from operating the car safely.

Similar to Gellatly et al. [3] we conducted a CI to explore the use of IVIS. The benefit of the CI, in contrast to a simple interview or questionnaire, is that the inquiry takes place in the users’ natural environment. This approach allowed us to gain a deeper understanding of the users’ actions. [1].

3. STUDY SETUP
Ten people participated in the study, aged between 24 and 63 years (average age: 39,6 years). Nine participants were male and only one was female, due to the fact that only two women responded to our announcement and only one decided to participate in the study. The cars in which the observation took place were equipped with one of the following three systems: The BMW iDrive, the Audi MMI or the RNS-E System from Audi (a previous model of the MMI system). Additionally to the central rotary knob all cars had control buttons on the multifunctional steering wheel. The study took place over a period of six weeks. The route for the rides was determined by the driver themselves in order to obtain “natural” driving conditions. One ride took one hour on average. Following the CI method, the researcher (sitting

in the front passenger seat) asked questions when the participant interacted with the IVIS and took notes, considering driving security. The conversations during the ride were recorded with a voice recorder. After the ride the researcher interviewed the participant aiming to identify user requirements and attitudes regarding the system. Moreover the participants were asked about their experiences when being observed during the ride (e.g. if they felt distracted). After the interview the researcher supplemented her notes with remembered impressions of the ride.

4. STUDY RESULTS (selected)

The CI allowed us to identify more than 15 different tertiary tasks, regarding the operation of the radio, the CD player, the navigation system, the mobile phone and the climate control. Some tasks were performed only with the multifunctional rotary knob; others were performed with the steering wheel control buttons. In the following the central results for RQ1-RQ3 are described.

4.1 Performed Tasks (RQ1)

Regarding the performed tasks we were especially interested in why and how drivers perform certain tasks with the central rotary knob. Although some tasks (e.g. setting the volume level when listening to the radio) could be performed more easily and quickly via the buttons on the steering wheel, they were performed with the central rotary knob. We found out that not only pragmatic qualities such as an easy and fast operation of the IVIS were important, but certain hedonic aspects (e.g. sound design). One driver for example especially enjoyed the sound that is produced when operating with the central rotary knob, so he hardly performed tasks via the buttons on the steering wheel.

Most of the drivers (seven of nine) activated the navigation system not to be guided to the defined destination, but for other reasons. The majority of drivers wanted to gain information about the arrival time or the distance to the final destination. Thus, the additional value of the navigation system providing more than just the route to the defined destination has to be considered in design decisions.

Moreover, participants did not see a necessity to use the voice command to make a call due to the simple operation of the telephone via the central rotary knob. They pointed out that the operation is similar to the operation of the mobile phone, e.g., there is a list of recently dialed numbers as well as frequently dialed numbers, which makes it easy to make a call.

4.2 Influence on Driving (RQ2)

Regarding RQ2 we explored the influence of interactions with the IVIS on the primary tasks of driving. Thereby, we were interested in interactions between tasks and context factors.

Especially under suddenly changing contextual conditions the operation of the IVIS (e.g. the navigation system and the telephone) had a striking influence on the primary task of driving. Two drivers, for example, barely managed to stop before a red traffic light while making a phone call and searching for a number in the directory. Four incidents in the car were observed while operating the navigation system. In one case the driver hardly realized that he was going to use the entrance of the underground car park instead of the exit to leave it. We can therefore conclude that also modern systems, aiming to increase drivers' concentration on the road have a high potential to increase distraction.

4.3 User Experience Factors and User Requirements (RQ3)

Regarding user experience, especially distraction was identified as an important factor. So far a row of possibilities exist to reduce distraction and enhance safety in the car, e.g. voice command to operate the navigation system or the multifunctional steering wheel, proclaiming to help the driver concentrating on the traffic and keeping focused on the road. Nevertheless our observations indicated that these options were rarely used. Although almost all cars were equipped with the possibility of voice command, the observations revealed that most drivers were not used to the service, and therefore avoided utilizing this functionality.

The user experience factor safety primarily played a role in connection with the navigation system. Participants felt secure when operating the navigation system, because they experienced to be less distracted, due to the easy and intuitive operation. Nevertheless we found out that operating the navigation system distracted participants, e.g. when calling up specific information from the map. A mismatch between perceived and actual safety has to be pointed out.

5. CONCLUSIONS AND FUTURE WORK

Although the study does not allow a generalization of the results (especially due to the small sample size), the methodological approach has proven to be valuable in order to investigate the use of IVIS in the car. As an improvement it is intended to add a second observer and a video camera (capturing the environment, the participant and the IVIS). This might influence the natural driving behavior, but it would lessen the burden for the researcher to take detailed notes of performed tasks, context factors, and participants' explanations. As a future work, it is planned to apply the method to explore driving behavior with respect to different context factors (e.g. icy roads in winter).

6. ACKNOWLEDGEMENTS

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Driver Distraction Analysis based on FFT of steering wheel angle

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Abstract

Driver analyzing has become an interesting field of research. Within this field, camera free systems are more and more in the scope of research groups all over the world. In order to enable a camera free state detection system, we focus on the steering wheel angle. In a simulator study, several data sets including different sorts of secondary tasks were collected and analyzed with the scope on typical patterns for distracted driving. Therefore, we use the Fast Fourier Transformation and focus on the spectra of the (distracted) steering wheel angle.

General Terms Driver Analyzer, Fast Fourier Transformation, Distracted Driving

1. Introduction

In our research, we focus on driver analysis and within this topic, we concentrate on driver inattentiveness. In comparison to other research groups focusing on this or a similar topic, we do not use any cameras to monitor the driver, but use sensor data from the car. In a simulator study , driving data for measuring driver distraction has been collected. The participants had to fulfill varying secondary tasks like using the navigation system, making phone calls, or inserting a CD into the multimedia system. After driving, participants were assessed concerning their distraction level on a scale from zero to three (zero stands for *no distraction*, one for *small distraction*, two for *distracted* and three for *highly distracted*). Our goal is to find significant patterns in the recorded data, especially in the steering wheel angle, which are typical for driving inattentively. For this purpose, we use the Fast Fourier Transformation (FFT) to identify differences in the spectral range of the data and to create filters or indicators for distracted driving.[1] Basics for our thoughts were the books and arcticles of [1–6].

[1] Distraction and Inattentiveness are used as synonyms.

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2. Characteristics of the Steering Wheel Angle

The steering wheel angle (stwa) is a one dimensional signal. The advantage of the stwa is that it is represented on every car, whereas data like time to lane crossing or road position are on the one hand depending on the stwa and on the other hand only available in premium class cars (and within this class, mostly only as an additional extra feature). Therefore, we decided to focus on the stwa. A typical spectrum of the stwa is shown in figure 1.

Figure 1. Spectra of the stwa over time.

3. Analyzing the spectra of the stwa

When calculating the FFT, we focussed on a time window of 10.24 seconds.These 10.24 seconds are the result of the spectral length of N=256 data points by a sampling rate of 25 Hz, which is used because of faster computation rates.Our basic idea is that there are differences in the spectra correlating with different distraction levels, i.e. the spectrum of the stwa for distraction level one looks different from the one for distraction level three. This idea is guided by our evaluation of the collected data. In figure 2, we show an example: The green bars belong to the distraction level three, whereas the blue bars represent level one. The sampling rate in this case was 200 Hz. We compare on the one hand the different distraction levels among each other (meaning level 1 vs level 2, 1 vs 3 and 2 vs 3) and on the other hand the spectra of the same distraction levels (meaning level 1 vs level 1, 2 vs 2 and 3 vs 3).

4. Results

In parallel to the FFT, we also performed some statistical analyses on the datasets. Therefore, we focused on the three tasks *telephoning* (T1), *navigation* (T2) and *insert a cd* (T3). The results can be seen in table 1. We have calculated the part of each distraction level (DL) in percent during a task. As we can see, inserting a cd into a radio is not a big problem any more for drivers, whereas telephoning or using the navigation system demands more concentration. A first important result is also that the slope between the values of position *n* and *n+1* is 2 degrees higher in distracted situations than in non-distracted situations.

All our datasets have a sampling rate of 25, 100 or 200 Hz.

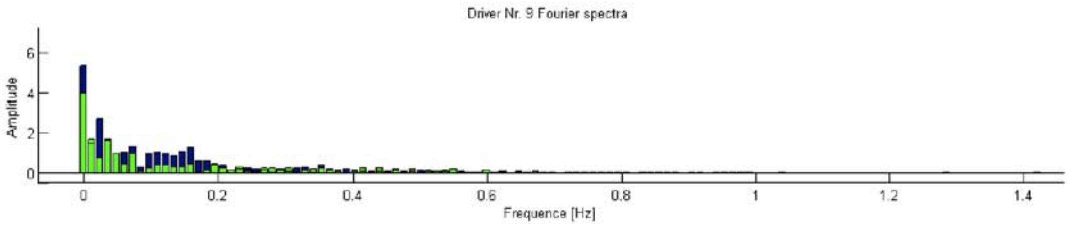

Figure 2. Fourier Spectra of Distraction Level 3 (blue) and zero (green). Sampling Rate 200 Hz. The x-axis shows the frequency area of the spectra, on the y-axis, one can see the amplitude. In comparison to figure 3, we zoomed into the frequency area of 0 to 1.4 Hz.

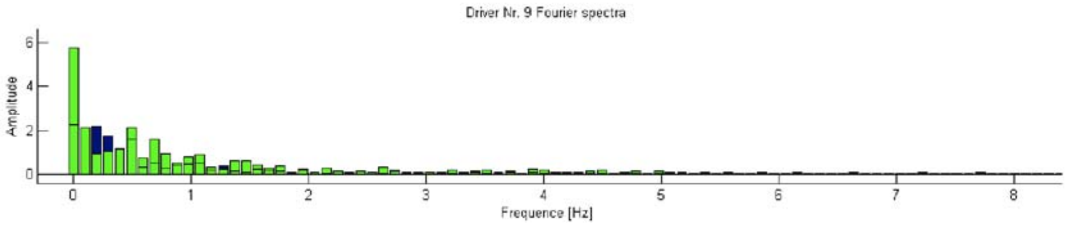

Figure 3. Fourier Spectra of distraction level 0 (green) and level 1 (blue).The x-axis shows the frequency area of the spectra, on the y-axis, one can see the amplitude.

	Driver 1			Driver 2			Driver 3		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
DL 0 [%]	21,4	97,9	98,7	10,3	80,8	99,4	25,0	14,1	7,2
DL 1 [%]	33,0	1,2	0,9	7,2	7,8	0,6	27,0	14,2	92,8
DL2 [%]	40,4	0,9	0,4	50,1	3,5	0	48,0	70,3	0
DL3 [%]	5,2	0	0	32,4	7,9	0	0	1,4	0

Table 1. Overview of the tasks and their corresponding distraction level

After calculating and analyzing the first Fourier Spectra, we can give the following first results. When comparing the spectra of distraction level zero respective one and three, we have similarities in the spectra concerning amplitude and frequency. In high distracted phases, we have always maximum values in the amplitude between 5 and 6, the major amplitude values are between 1 and 3. The main frequency parts are between 0 and 3 Hz. In zero or low distracted phases, we can observe an amplitude of, average, two as a maximum and 0 to 1.5 in the frequency 0 and 3 Hz as main frequency rate. (See figure 3 as an example.)

5. Next Steps

As next steps, we have to validate the correctness of these results on the one hand by analyzing further data sets and other sampling rates. On the other hand, we have to create an offline algorithm, on which we can test our results by using live data from a car.

Building upon these next steps, we plan to create a classification system for an online algorithm, which is able to detect inattentiveness during real driving. For this purpose, we will introduce a set of classes, in which different stwa's are analyzed depending on the driving scenario (e.g. lane change, normal driving, overtaking, or secondary tasks) and the distraction level.

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Gas Station Creative Probing: The Front Seat Passenger

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ABSTRACT

Creative probing is a decent method to record a point of view from participants towards their situational experience by making particular ideas, motivations or desires visible. Regarding the car context, designers often use the target group of drivers for in-car interfaces design. In this work, we describe an adopted creative probing method to involve the front seat passengers in the design process. To recruit the desired target group we propose the gas station as recruiting area, due to the high frequency of possible participants who are at this point in direct contact with the respective context.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Theory and methods

Keywords

Creative Probing, Gas Station, Advanced Automotive User Interfaces, Front Seat Passenger

1. INTRODUCTION

In this paper, we present a creative probing approach conducted at a gas station using the creative card technique [1], to investigate front seat passengers' informational needs in different driving situations. The creative card approach for the context car already showed its potential in a previous study [3]. The gas station context is a promising area for conducting studies [2], as it is most likely a place to meet the desired target group. The aim of this approach is to adapt the traditional recruiting process by transferring it into an area that is related to the desired target group.

2. GAS STATION PROBING

The gas station recruiting approach was developed during a study that aimed to get inspirations for innovative and creative user interfaces for the front seat passenger. The study goal was to get a direct connection to a hard-to-reach target group in a short time and receive a diverse set of creative materials that serves as inspiration for designing future front seat passenger cockpits. We assumed that a creative probing study at a gas station would ease the recruiting process through the high frequency of possible participants. Another benefit was that the participants could return the probing booklet independently at the gas station, which was arranged in advance with the gas station staff. We expected a higher returning rate as the booklet did not need to be returned by mail. Using the gas station as a recruiting area is grounded in an awareness that essential aspects of the creative probes needed to be adapted to the gas station. Thus, in the next sections considerations towards the environment, the target group and the study process are described.

The Environment The selected gas stations need to be regarded in advance since their customers can vary widely depending on the surrounding area. Consistent with the respective target group, it needs to be considered if participants are required that return frequently to the gas station or if it is sufficient to stop once. For example, highway gas stations have a higher occurrence of truck drivers and transients. Near national boarders the amount of fuel tourists increases depending on the fuel prices in the affected countries. Otherwise, the amount of local, returning gas station customers increases at gas stations in the center of a city. Nevertheless, the frequency of local customer groups also varies according to the surrounding area (in a central business district there are more customers in the morning and in the evening) or when e.g. roadworks block the access to the gas station (general decrease of customer frequency).

Study Target Group To address the issue that driver and front seat passenger are not necessarily driving together regularly, the researchers need to ask during the recruiting if they are able to perform the task together. Although front seat passengers are the target group within this probing study, the incentives focus on the driver to take him/her into responsibility for returning the probe. It seems more likely that the driver motivates the front seat passenger to finish the tasks and then returns to the gas station in comparison to vice versa motivation.

Study Process Due to the gas station environment, it is advisable to split the probing phase into a first starting exercise performed at the gas station and tasks to be conducted afterwards during a specified period of time. This is

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reasoned by reducing the duration for explaining the probing study aim to the participants and making sure that the study is conducted in a proper way. The starting task at the gas station (e.g. sketch a future user interface for front seat passengers) needs to be explained by the researchers first, and then the participants subsequently have to conduct the exercice in the context of their own car (see figure 1). The participants are asked to complete this task on their own to make sure they are not influenced by the researchers.

Afterwards, it is possible to get additional data by performing a short-term task that provides additional information. (e.g. the participants could be asked to place the sketched interface in the front seat passenger area at the most convenient position and a picture can be taken by the researcher, see figure 2). Finally, the probing booklet needs to be handed over to the participants. It contains further tasks that the participants need to conduct while being a front seat passenger during car trips. The participants have to return the booklets to the gas station within a preset period of time to receive the incentive.

Figure 1: Gas station creative probing: a participant conducts an exercise in the front seat area

Study Example The method was initially used in August 2011 and conducted for 7 days between 8 am and 10 pm. The incentive was a voucher for a premium car washing program. The researchers distributed the probing booklets at two gas stations. On average, it took about 15 minutes to explain the task to the participants and let them conduct the starting task. It was sometimes necessary that the participants' driver parked their car in a parking slot after fueling the car. A total of 90 probing booklets were distributed and 80 probes from the starting exercise collected. After the preset period of one month 30 probes were returned and collected by the gas station staff. This result is seen as promising for ad-hoc recruited participants, especially in conjunction with the high number of creative material gained trough the starting exercise.

3. METHODOLOGICAL REMARKS

In the following we describe considerations towards the methodological process that were observed during an initial study. During their overall time at the gas station, drivers were less busy and the researchers experienced that they were mostly willing to answer some questions and could ap-

Figure 2: Creative probe: demonstrating the position of an in-car interface for front seat passengers

praise if their front seat passenger was willing to participate. Participants who took part were courageous and interested in the topic, why a high number of creative materials could be collected. Nevertheless, some people refused straight away, as they thought the researchers were selling goods or asking for donations. One behavior of refusing was to claim to be in a hurry. Some customers started to rush into the gas station towards the counter and rushed back again to their car. It could not be examined, if the customers pretended to be in a hurry, but the accumulation of incidents suggested that some of them only proclaimed to be. In general, the best moment to ask the participants was after the refueling, since a few drivers forgot to pay and needed to be reminded by the gas station staff.

4. CONCLUSION

We presented a creative probing approach at a gas station. The recruiting of participants in an area where the front seat passenger target group can be met showed its potential, as a high number of creative materials could be gained within a month. Considering the variety of qualitative materials gained, it may be a valuable approach to recruit in areas like at a car dealer or a garage, where people have more time for elaborate exercises.

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A New Icon Selection Test for the Automotive Domain Based on Relevant ISO Usability Criteria

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ABSTRACT
In the automotive domain icons are popular and widespread, but it is not absolutely clear how to select icons according to a number of usability requirements. In this paper, we introduce a procedure for the evaluation of icons. Besides taking into account former icon test approaches, this new test is the first to explicitly consider various relevant criteria from current ISO standards in the field of Human-Computer-Interaction. We provide a test description including four diverse subtasks, and provide exemplary results for the icon drafts belonging to two features.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Evaluation/methodology, User centered design*

General Terms
Measurement, Performance, Design, Human Factors

Keywords
Icon, selection, test, understandability, learnability, memorability

1. INTRODUCTION
User-friendly designed icons can influence a human machine interface positively in several ways: First, they can be found and recognized quicker, they need much less space than text, they are better memorable, and are not bound to a specific language [1]. According to ISO/TR 16352 [2] their use can also be seen critically: If the meaning of the respective icons is not obvious and captured entirely, an increasing error rate could result. Thus, icons have to fulfill various criteria, such as manifestness (i.e. most people associate the same, intended concept [3]). Similarly, ISO norm 9241 [4] has defined certain criteria that interactive systems have to meet. For icons as part of an in-vehicle driver information or assistance system, the most important criteria are task adequacy, self-descriptiveness, conformity to expectations, and learning supportiveness. In literature, there are few attempts to create icon-based tests. In [5] the subjects' task was to freely name the meaning of presented icons. Afterwards, raters evaluated the answers with the help of a nine-step scale. Another possibility is to present several icon drafts together with the written meaning and let subjects rate, which one captures the intended meaning best [6]. In order to test predesigned icons according to the various design criteria for human-machine-interaction, we developed a new method, which exceeds previously applied techniques.

2. ICON SET
As an evaluation corpus for this new procedure, we used 18 diverse functionalities from the automotive domain, which were extracted from the car-to-x communication research project sim^{TD}. By pressing the respective icon, more detailed information about the feature can be accessed on a larger screen area. For each content (warning or information) three icons were created, resulting in 54 icons overall. Warning icons had a red triangular frame according to German hazard traffic signs, whereas information icons displayed a rectangular, blue frame (cf. Figure 1).

Figure 1. Items for a) warning icons "Attention, heavy rain!" and for b) information icons "Remaining red light time".

Notably, the information of most warning icons was quite precise, not too complex, and easy to picture (e.g. icy conditions, a braking car). In contrast, the contents of information icons were mostly abstract and rather hard to design (e.g. dynamic route planning, street foresight). Accordingly, we expect an icon test being able to differentiate according to ISO criteria, to reveal better results for warning icons than for information icons.

3. ICON TEST
With reference to the aforementioned, relevant ISO criteria, we developed four different tasks. The entire test was conducted with 24 participants (mean age = 30.7, range = 20-57; 12 males and 12 females).

3.1 Task 1
The first task was designed to test the icons' manifestness, understandability, and task adequacy. When looking for specific information, a user should be able to choose the corresponding icon. Moreover, when encountering a new icon, the intended meaning should immediately be evident. In the first task all icons were presented sequentially in their original size (1.1"x 0.8") on a 7" display with a viewing distance of about 20". The subject should assess the respective meaning by ranking four possible descriptions available. In order to achieve additional, reasonable interpretations, two independent subjects had generated these alternatives via free associations prior to the actual test. The statement fitting best from the subjects' point of view, should be labeled with a '1', the second best with a '2', and so on. If the correct meaning was selected in first place, the icon was later evaluated with three points; in second place it received two points and so on. In order to control for possible sequence and motivation effects, the 54 icons were divided into three equal blocks containing one icon for each feature. Block order was counterbalanced between subjects. After having finished the whole first task, the intended "correct" meaning of each icon was revealed.

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3.2 Task 2

In addition, icons should be concordant with the users' expectation: After selecting an icon, the expected information appears. Therefore, subjects should assign each icon to a more detailed illustration of the information, which it represents. For this test, printouts were prepared of all 54 icons and of the 18 larger, detailed feature information screens. Subjects assigned the small icons to the larger information screens manually. Encoded numbers on the backside of the printouts helped the experimenter to take down the results. Particularly with regard to information and warning icons, it can be assessed, whether a graphical distinction is reasonable and prevents category mix-ups. Icons that were assigned correctly, gathered one point in this test.

3.3 Task 3

Following [6], in the third task subjects rated which of the three alternative icons captures the intended meaning the best. In an evaluation booklet, one feature after the other was shown together with a short description of its intended content and its three respective icon drafts. The best icon should be labeled with '1', the middle one with '2', and the worst with '3'. In case of labeling an icon with '1' the icon received two points, whereas '2' gained one, and '3' obtained no points.

3.4 Task 4

The last task was designed as a free recall task. The purpose was to figure out, how well learnable and memorable the respective icons are. To achieve this goal, three days after completion of task one to three, we sent a list containing all 54 icons to the subjects via email. The icons were again divided into three blocks, and their sequence was balanced between subjects like in the first task, but the order was changed. In addition, the email message contained instructions as well as an example. The task was to describe the correct meaning of each icon shortly and precisely. Furthermore, the subjects were advised to respond within 24 hours. The answers were evaluated by two independent raters with the help of a four level rating scale ranging from „The description corresponds the meaning completely" to "The description does not correspond with the meaning at all". At best an icon could achieve three points in this task, at worst it earned no points.

3.5 Aggregation Procedure

As the four tasks have equal priority in standard evaluation cases, differences between the tasks' maximum scores had to be outweighed, before adding up the single scores. In the second and third task, only one or respectively two points could be achieved. These scores were multiplied by the factors 3 and 1.5. Another possible way is to assign 3 points to correctly assigned icons in task 2, and accordingly 3 or 1.5 points in task 3. This allows skipping the multiplication. In any case, the maximum score for each task is three points, resulting in a total value from zero up to twelve points for each icon. Eight points were defined as a threshold for using an icon draft without major revision.

4. RESULTS

Below, we present exemplary results for the warning content „Attention, heavy rain!" and for the more abstract information feature "remaining red light time" (cf. Figure 1). Scores for each icon in tasks one to four and their total value can be taken from Table 1. Pairwise comparisons (bonferroni corrected) revealed, that the second warning icon was significantly better than icon number 1 ($p < .05$ and icon 3 ($p < .001$). Information icon number 2 earned a significantly higher score than icon 1 ($p < .001$) and icon 3 ($p < .001$).

Table 1. Scores for two exemplary, car-to-x based features.

Feature	'Attention, heavy rain!'			'Remaining red light time'		
Icon	1.	2.	3.	1.	2.	3.
Task 1	2.4	2.7	2.8	2.2	2.8	2.2
Task 2 *(x3)*	1	1	1	1	0.9	1
Task 3 *(x1.5)*	0.5	1.9	0.5	1.1	1.4	0.4
Task 4	2.5	2.9	2.9	2.6	2.9	2.8
Total	8.9	11.5	9.5	9.6	10.8	8.7

This demonstrates, that our new icon test is able to differentiate between different illustrations by the combination of tests, as we had intended. Also, subjects overall rated warning icons significantly higher than information icons (mean = 9.6 vs. 9.0; $t(46) = 5.2$, $p < .001$) as we had expected from the first. By the way, for each of the 18 features, we identified at least one usable icon (score > 8) and got insights for which of those improvement might still be worthwhile (score < 10).

5. SUMMARY & CONCLUSION

The aim of this study was to develop a test that verifies icons with regard to several ISO criteria. By this icon test, pictograms for different warning and information features were evaluated. First of all, the results show that this icon test can differentiate between diverse forms of illustration and fundamentally support the selection process. Moreover, compared with former techniques, it is a more extensive method to review icons and especially fits the automotive domain. Furthermore, if needed, the test could (carefully) be adapted to specific requirements by changing the weighting of tasks or selecting just a subset of tasks. For the future, it is still necessary to look closer into the quality criteria of this test (validity, reliability), as well as an additional measure for consistency regarding the icons of a final set could be introduced as a next step.

6. ACKNOWLEDGMENTS

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The Process of Creating an IVAT Plug-in: Mirror Checking

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ABSTRACT
In this paper, we discuss the process of creating a mirror checking plug-in for a personalized, adaptive program used to assist drivers who have had a traumatic brain injury (In-Vehicle Assistive Technology, or IVAT). Our aim in the current paper is to outline the procedure utilized in the creation of the current IVAT plug-in and to highlight the importance of user-centered design in an application such as this. We discuss the myriad of decision points and design possibilities and how we base implementation in theory about user needs and capabilities.

Categories and Subject Descriptors
H.5.2. **[Information Interfaces and Presentation (e.g., HCI)]**: User Interfaces – interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design

General Terms
Design, Human Factors.

Keywords
User Interface, Traumatic Brain Injury, Assistive Technology, Human Factors, Plug-in Design

1. INTRODUCTION
Each year 1.5 million Americans report new brain injuries in addition to the 5.3 million already identified as having a traumatic brain injury (TBI) [1]. While the injuries significantly impact their lives, these individuals often attempt to become fully independent post-injury, including undertaking independent driving [2]. The cognitively and perceptually demanding task of driving, however, can create issues for individuals with a TBI due to the consequent impairment in cognitive functioning it presents [2]. Individuals who have experienced TBIs have often reported problems with safe driving practices, creating situations in which driving can be dangerous [3].

2. IVAT Background
To assist with the re-integration of individuals into mainstream society following TBIs, the Sonification Laboratory at the Georgia Institute of Technology has been working with the Shepherd Center to create and implement an In-Vehicle Assistive Technology (IVAT) system. Rehabilitation experts at the Shepherd Center originally developed a hardware device (a "three-button box"), called the electronic driving coach (EDC), for a case study of an individual with a TBI [4]. The Sonficiation Lab has extended and expanded this proof-of-concept into a complete software system that can now be installed onto a car PC integrated directly into the vehicle [5]. From the outset researchers sought to understand user needs for the global IVAT system through interviews and focus groups, as well as iterative evaluations of prototypes with potential users and driving rehabilitators [5]. That research identified a set of tasks performed while driving that could be affected by a TBI. The vision of the future IVAT system is a system of plug-ins, each designed specifically for one of these tasks. These plug-ins could be employed alone or in combination with others, ultimately creating a personalized and adaptive driving system for any given user. It is now important to ensure that the development and design of each one of these IVAT plug-ins is appropriate and effective. Drivers with TBIs present unique challenges in developing such an automotive user interface.

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3. The Plug-in: Mirror Checking
3.1 Choosing Mirror Checking
Considering driving as a whole, maintaining spatial and situational awareness (SA) is a vital part of safe driving [6]. Given the high priority of and TBI drivers' frequent problems with SA, facilitating the task of checking mirrors was selected to be the function of the first purpose-built IVAT plug-in (see e.g., [7] for the empirical research that assesses driver situation awareness using mirror checking).

3.2 Primary Considerations
During the design process the overall goal of a plug-in must be well established. In the case of this mirror checking application, the goal was to increase the users' awareness of their surroundings by reminding them to check their mirrors, making them safer and more engaged drivers. The system must accomplish this goal without adding significantly to the user's cognitive load and inadvertently impairing his or her ability to drive. Additionally, the plug-in must be compelling enough to keep the user's attention, which has been shown to be important to drivers with a TBI (because drivers with a TBI frequently forget that they are driving) [5]. Furthermore, the system must unify the mirror-checking task with driving, and not create a situation with dual tasks.

3.3 Planning the System
The system has two basic functions: issuing a reminder to complete a task and registering completion of the task. The first consists both of determining appropriate times to issue reminders and of the reminder itself. The second also requires two steps, appropriately recognizing completion and communicating that recognition. By separating these steps, each variable can be considered in stride during development and receive either a design decision based on previous knowledge and research or an empirical investigation.

3.4 Making Design Decisions
An early decision was made to exploit the utility of multimodal interfaces to maximize the effectiveness of a notification while minimizing its additional cognitive load. This practice is supported by multiple resources theory and discussed within the context of the IVAT project in concurrent research [8,9]. During the development of the mirror checking plug-in, researchers were

aware of multiple methods to accomplish the goal of acknowledging the completion of the task. Accordingly, in order to allow for upgrades or changes, the system was constructed with the ability to flexibly utilize a touch screen system, buttons on the steering wheel, and eye-tracking devices that would allow the system to independently recognize mirror-checking behavior. These design decisions were then applied to develop a basic prototype.

3.5 Primary System

In its first implementation, the primary system could issue the reminder across both audio and visual modalities. The visual modality consisted of illuminating mirror icons on a touch screen head unit with the option of expansion to include in subsequent implementations small lights on the side mirror casings and the top of the rear view mirror. The audio component of the notification was a major chord differentiated across space and by mirror as follows: the driver side mirror notification was the root note of a chord (e.g., C) issued from the front-left speaker, the rear view mirror notification was the musical fifth (e.g., G) issued from both front speakers (thereby appearing to come from the center), and the passenger side mirror notification was the musical third note (e.g., E) issued from the front-right speaker. These notes were issued sequentially as the notification and again to indicate recognition of completion. The manner in which the driver indicated completion included two options: either the driver pressed anywhere on the touch screen of the head unit or he or she utilized a button on the steering wheel. Both methods of input allow for a simple, one-step indication that the driver has checked the mirrors.

3.6 Testing the Primary System

In order to evaluate a primary system's variables and their effect on cognitive load as well as user preference, user studies and more plug-in specific practical design tests are required. In the current plug-in development, the user testing consisted of a comparison of various visual and audio options for the output as well as the method of input—steering wheel buttons, a single touch screen icons, or a touch screen icon for each mirror. Testing was done on the Georgia Tech School of Psychology's National Advanced Driving Simulator MiniSim and an in-vehicle PC running Centrafuse—an operating system designed specifically for direct integration into an automobile's onboard computer—connected to a seven-inch touch screen display located identically to a head unit's position in a vehicle. Using the NASA TLX cognitive-load scale and user-preference Likert scales as well as an analysis of the effective change in mirror-checking behavior, determinations concerning the optimal input and output arrangement would be made. Following that ongoing research, a usability study with the target population of individuals with TBIs has been planned, with special consideration for their feedback.

3.7 Finalization

Following the completion of both sections of testing, a final product will be implemented and added to the IVAT program. This final product will be expected to utilize the multimodal interface as a subtle but effective method of conveying the information to the driver. As more plug-ins are developed, the integration of each with the others will be investigated. This process will also employ user-centered design in order to ensure that the program as a whole is usable and still accomplishes primary goals.

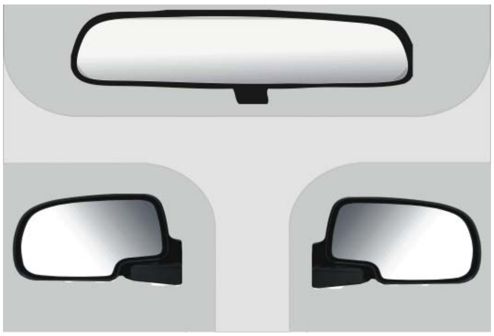

Figure 1. Figure 1 shows the basic layout and design pre plug-in creation of the touch screen based interaction.

4. Discussion

Through employing user-centered design, the final product of this creation process will be made specifically for the users in order to be more effective at addressing their specific needs. Using this process also allows for flexibility in future extension of the plug-in, whether it be to other users or separate populations for which the system is adapted, such as inexperienced or elderly drivers.

5. ACKNOWLEDGMENTS

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Personas for On-Board Diagnostics – User types of drivers dealing with malfunction in e-cars

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ABSTRACT
This paper focuses on identifying user types of drivers dealing with malfunction in electric cars reported by On-Board Diagnostics. An expert round and four focus groups with drivers identified typical behavior patterns which were validated by surveys. As a result we got three personas for On-Board Diagnostics, which can be used for a more user-centered design of such diagnosis systems.

Categories and Subject Descriptors
H [**Information Systems**]: H.5 Information Interfaces and Presentation—*H.5.2 User Interfaces*; B [**Hardware**]: B.4 Input/Output and Data Communications—*B.4.2 Input/Output Devices*

Keywords
Personas, User, On-Board Diagnostics, E-Mobility

1. INTRODUCTION
Professionally and privately, the own car is the most important means of transport for drivers which they prefer to all other modes of transportation [4]. To ensure its flexibility and reliability the permanent monitoring of the drive is inevitable. This is what On-Board Diagnostics (OBD) stands for – the self-diagnostic and reporting capability of the car [9]. In terms of malfunction the driver is warned and gains an appropriate message as stipulated in [3]. Appropriate means, that the message meets the needs and requirements of different types of drivers with their different characteristics. To capture the diversity of drivers and their need for information, a driver analysis is required, which is documented in a comprehensible and goal-oriented description of the driver.

The bases for this are personas that have been developed in the research project PräDEM [2, 8]. Personas are "fictitious, specific, concrete representations of target users." [6] Personas are not real people, but they replace the abstract mass of future users through prototypical fictional personalities with specific properties [1].

The persona-method is an established tool in user-centered design to give a face to a user group, reflecting their needs and representing the individual users with their different characteristics [5]. The advantage of the user description using personas to the definition of user groups is mainly in the lifelike representation of potential users. The description makes it easier for project team members to visualize the user in all phases of development and to consider his needs [7]. Due to this, within the PräDEM-project personas served to convey a clear idea about the behavior, attitudes, goals and motivation of future users, to create a common design goal in user-centered design process and to facilitate the communication of user requirements.

2. A PERSONA SET IS CREATED
The approach to model the personas is oriented oneself by the persona lifecycle based on [6].

In a first step, a project internal expert round with four representatives from ergonomics and automotive research and development proposed two main user types of drivers in relation to OBD, enthusiasts and pragmatists. This first rough classification served as a bridge to the future personas. The enthusiast describes car- and technology-avid drivers with a preference for self-repair, for whom their own car occupies a particularly high priority. In contrast, the pragmatist describes drivers with low affinity for cars and technology, who see their car primarily as a means of locomotion and transportation for everyday use.

The expert round managed to simultaneously provide the basis for the next step of persona development, the identification of behavioral variables and their values for the formation of personas. As a result, four categories emerged with concrete variables to be gathered:

- Demographic information – name, age, gender
- Experience and skills – technical education, occupation, diagnostic experience, car breakdown experience
- Personality characteristics – affinity for cars and technology, innovation, interaction behavior, perception of aesthetics
- Mobility behavior – driving experience, route profile, environmental awareness, housing

Four focus groups with a total of 20 drivers in combination with user questionnaires provided qualitative data regarding expectations and wishes about the information content, interaction

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and visual representation of OBD, as well as quantitative data regarding the variable attribution. Based on these data, the drivers were assigned within the defined variables and patterns in their behavior were identified. The results confirmed the assumptions of the initially identified user types of enthusiasts and pragmatists. In addition, there was a third major type of users, the curious. Just like the pragmatist, the curious sees his car mainly as an everyday means of transportation, but also is interested in its technology and operation.

For each identified behavior patterns the descriptive data were summarized and recorded in note form. These persona frameworks were supplemented by descriptions of each attribute and additional data, including graphics, suitable citations, vivid descriptions and an exemplary experience of car breakdown in the form of a "day-in-the-life" scenario. These elements give the framework a personality, breathe life into them and let them mature into fully-fledged personas.

The constructed personas were back checked on the collected user data to eliminate significant deviations of concretized characteristics and narrative elements. A final survey of selected drivers was used to verify the consistency of the personas.

3. RESULTS FROM THE PROJECT PRÄDEM

Three validated personas of OBD were extracted, which are described briefly in the following:

- Daniela – The pragmatist
- Mike – The curious
- Ralf – The enthusiast

Daniela describes drivers who are reliant on their cars in everyday work, who see their cars as a commodity and who possess neither deep technical understanding nor car-specific expertise. Daniela expects to be flexible, mobile and informed in an understandable form about any kind of malfunction. Mike describes short-haul drivers with basic technical understanding and slightly car-specific expertise. From OBD he expects high information content in order to expand his own expertise in this area. Ralf describes commuters with a profound technical understanding and solid car-specific expertise. He expects from OBD detailed diagnostic information and the opportunity to fix malfunctions by hand.

In the project PräDEM, these personas served as a concrete design goal and means of communication for the development and evaluation of an ergonomically high-quality display and interaction concept for predictive OBD in electric cars. They allowed all stakeholders involved to develop a common understanding of the drivers and to consider their perspective when making decisions.

4. CONCLUSION

The obtained set of personas provides a good overview of the diversity in usage patterns and the expectations, as well as the goals associated with the use of OBD. The combination of expert round, focus groups, user questionnaires and surveys ensured that the classification and behavior of the personas reflect the real driver adequately.

The personas originated from the context of e-mobility. Previous work showed that they represent an effective means to describe the driver in dealing with OBD messages. The adaptation of the personas on further drive concepts provides a way to use them for a more user-centered design of diagnosis systems in the automotive sector. Nevertheless, personas represent only an image of real users and cannot entirely replace them.

5. ACKNOWLEDGMENTS

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On Detecting Distracted Driving Using Readily-Available Vehicle Sensors: Preliminary Results

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ABSTRACT

This paper reports on-going work in detecting distracted driving using readily-available vehicle sensors. The research executed a field study involving 67 participants driving an instrumented military vehicle (HMMWV) on dirt roads while intermittently performing three different secondary, distracting tasks. This poster describes the experimental protocol followed as well as early results from the analysis of the data, including the features we have generated from the raw data.

Categories and Subject Descriptors

I [**Computing Methodologies**]: I.5. Pattern Recognition—*I.5.2 Design Methodology: Classifier design and evaluation, feature evaluation & detection, pattern analysis*.

General Terms

Algorithms, Measurement, Performance, Experimentation, Human Factors.

Keywords

Distracted driving detection. readily-available sensors, machine learning.

1. INTRODUCTION

The goal of this research is to build a software-based classifier that can detect distracted driving through a stream of vehicle sensor inputs using a military vehicle on a dirt course. This work attempts to extend simulator studies that suggest that distracted driving may be captured by readily available sensors in the field [1,2,4]. Although, this technology maybe used to develop behavioral intervention strategies in the future, the current research focuses on the detection ability of the classifier.

The sensors used to develop the classifier were restricted to those that were inherent or “readily available.” This restriction was motivated by the desire to simplify the system, to reduce expense, and to reduce dependence on exotic sensors. Further, military environments are less structured than other driving environments and may lack features that other sensors require (e.g. lane markings for lane departure sensors) [3]. In addition, military operations include a variety of weather conditions that may adversely affect more exotic sensor packages. Thus, the use of more exotic sensors may not be plausible.

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2. EXPERIMENT

2.1 Experimental Method

2.1.1 Participants

Sixty-seven participants, ages 22-50, drove a military HMWVV on a dirt road on Kirtland Air Force Base in Albuquerque, NM. All drivers reported possessing a current driver’s license and normal or corrected to normal vision. All participants were treated ethically and in accordance with the guidelines of APA and the HSB at Sandia National Laboratories.

2.2 Materials and Apparatus

2.2.1 Attention light

Participants responded to an attention light, which was a cluster of LEDs was mounted in the driver’s field of view on the windshield. At random intervals, this light illuminated and participants pressed a button strapped to their thumbs in order to turn the light off as quickly as possible. This light simulated drivers’ reaction times to roadway events.

2.2.2 Distraction Tasks

This set of tasks was chosen to be distracting to the driver without exposing the driver to undue risk. In particular, visuo-motor modes of interaction were specifically chosen because of their significant interference with the driving task [5]. All of the tasks required drivers to periodically look away from the roadway and to manually interact with a touch-screen interface.

Each distraction task was randomly generated. Each distraction block was triggered by GPS location along the course. This approach ensured that each participant experienced the same distraction task presentation at the same position along the course. An auditory cue (“Begin Task”) alerted the driver to perform the distraction task. A second auditory cue (“End Task”) indicated that the distraction task was complete.

2.2.2.1 Short-glance task

During the short-glance task, participants monitored a series of circles on a touch screen. Participants' task was to indicate which circle was highlighted immediately before all circles turned red. Participants accomplished this by touching the last-highlighted circle on the touch screen. This task required the driver to share visual attention between the road and the task, glancing back and forth for short periods. The overall distraction (involving approximately 10 responses) lasted approximately one minute per block. There were 13 blocks during the 30-minute experimental driving loop.

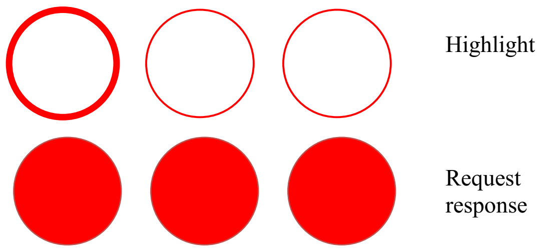

Figure 1: Dots for Short and Long Glance Tasks

2.2.2.2 Long-Glance Task

The long-glance task used the same dot row previously discussed, with the exception that 4 dots were randomly presented for 500ms each followed by 100ms of OFF time. The task required participants to remember the sequence of dot presentations, and when prompted, to touch the circles in that sequence in order to score a correct answer. This task required a longer glance than the short-glance task.

2.2.2.3 Table Task

Table 1 : Table Task

A	1	B	1	E	1
T	3	T	2	Z	3
C	6	Z	6	B	6
D	4	D	5	F	4
B	9	A	9	C	9
E	2	F	4	A	2
F	8	E	3	D	8
Z	5	C	7	T	5

During the table task, a six-column table was presented with alternating letter and number columns. The letters were associated with radio call signs (e.g. A=alpha, B=beta, etc.). An auditory cue was given with the call sign as the table was displayed. The task was to search each letter column for the call sign letter and to identify the digit to the right of it. Participants entered the three digit code on a touch screen keypad. After entering the first digit, the table disappeared, requiring the driver to memorize the 3-digit sequence before entering their response. The assignment of digits to letters and the order of letter and number presentations in the table were randomly generated for each presentation.

2.3 Procedure

Before the experiment began, participants practiced the three different distraction tasks in the stationary vehicle. Afterwards, they were instructed to maintain a 20mph speed limit and drove approximately one quarter of the course in order to gain familiarity with the vehicle. Then, they practiced each of the distraction tasks sequentially while driving.

After practice, participants executed four different driving conditions: 1) a baseline condition, in which participants drove without completing a distraction task, 2) a condition in which participants completed the short-glance task, 3) a condition in which participants completed the long-glance task, and 4) a condition in which participants completed the table task. The order of these conditions was counterbalanced across participants. With the exception of the practice period, participants completed only one type of distraction task type within a driving condition. The experiment took approximately 3.5 hours to complete.

3. PRELIMINARY DATA ANALYSIS

3.1 Data Collection

The 13 vehicle data sensors used to build features included brake, throttle, steering, roll, pitch, yaw angles and rates, 3-axis accelerations, ground speed. The vehicle data was updated at 4Hz and stored in a file with timestamps along with time stamped distraction begin and end codes, response codes (correct, wrong, timeout), and abort codes. One file per participant for each of the four conditions was stored.

3.2 Feature Generation

The raw sensor data was processed in 5 second windows consisting of 20 samples. Features such as mean, slope, range, and standard deviation were computed. In addition, features like reversals (for steering and throttle) were computed with different gaps defining the size of a countable reversal.

3.3 Early Results

Using simple logistic regression, data from individual subjects was used to build a model and test its accuracy per subject. This works no better than chance on some subjects while for others (approximately 25%) we can get AUC measures between 70% and 75%. In addition, this analysis reveals that certain features, notably the reversals features, are consistently the most predictive features as indicated by their p-values across many subject models. We do not claim that this simple regression model is the best one, but rather are using it as a tool to investigate the effects of distraction on driving for different subjects. It appears that some subjects cope extremely well with the distraction task while driving as shown by a lack of predictability of distraction from driving features.

4. ACKNOWLEDGEMENTS

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Natural and Intuitive Hand Gestures: A Substitute for Traditional Vehicle Control?

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ABSTRACT

This poster aims at discussing the potential of natural, intuitive hand poses and gestures used for interaction with standard applications in a vehicle while driving. Test drivers liked this natural type of interface and indicated that in-vehicle function control with intuitive hand gestures is a promising approach, which they would like to see in real cars in the future.

1. INTERACTION WITH THE VEHICLE

Driving, and in particular interaction with and control of information and assistance systems in a car, gets more and more complex because of the increasing number of buttons, switches, knobs, or the multi-stage functionality of controls such as *BMW iDrive* or *Audi MMI*. A possible consequence from the excessive information is cognitive overload, affecting driving performance, and finally resulting in driver distraction. This complexity-overload relation emphasizes the importance of novel solutions for future vehicular interfaces to keep the driver's workload low. As the visual and auditory channels are mainly responsible for driving and driving related tasks, interaction modalities discharging these channels bear good prospects to reach this objective. On the other hand, however, care must be taken that driving safety is not affected, e. g., due to a violation of the "eyes on the road, hands on the wheel" paradigm.

1.1 Gestural interaction in vehicular UI's

With emergence of motion controllers such as Wii Remote/Nunchuk, PlayStation Move, or Microsoft Kinect, interaction with computer games was revolutionized, as, for the first time, button/stick based controllers previously used were replaced with natural interaction based on intuitive gestures and body postures inspired from reality. The use of gestural interfaces carries also lot of potential for (driving unrelated) control tasks in vehicles, supported by recent work reporting fewer driving errors when using gestural interfaces in the car as compared to common "physical" interfaces [1]. In this work, we focus on gestural interaction and use it for application control in the car. Static hand poses/dynamic hand gestures are (i) performed while driving, (ii) recorded with a RGBD depth camera (*Kinect*), (iii) evaluated with a recognition framework, and finally (iv) reviewed systematically.

For the initial setting, predefinitions were made to use the interface on the European market and in highway driving only. This allows the gesture set to be restricted to the interaction behavior of Europeans (to address the issue of cultural differences) and, as most European cars have a manual shift, to use the gearshift area for gathering driver gestures. Furthermore, we clearly accentuate that this setting does not compromise the "hands on the wheel" paradigm as (i) only secondary functions are controlled, thus timing is not an issue and interaction is not necessary at all, (ii) the workload of a driver is lowest on the highway [4], and (iii) from a opinion survey it came up that less than 15% out of >150 respondents drive with both hands on the wheel while on the highway.

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1.1.1 *Considerations on the gesture set*

While the definition of gestures to control computer games is often straightforward and mostly borrowed from the real world, e. g., a player of a tennis game would immediately know about how to use the controller without learning, this is in general not the case for "artificial" interaction as dominant in the vehicle. Interface designers often define gestures on its own preferences, evaluate them in user studies, apply modifications and finally teach the users on how to employ a gesture to interact with the system in the desired manner. This is, of course, not the optimal way, as users may have different personal preferences of how they would like to interact with the system to perform a certain task. The predefinition of gestures independent from a driver's personal bias is indeed not the preferred way – in contrast, it is essential that gesture based interaction is observed as natural as possible in order to keep driver's mental workload low (that is, to avoid that he/she has to think about which gesture to use for what action or how a specific gesture is defined).

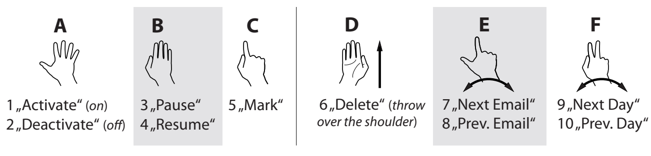

Figure 1: Static hand poses (left)/dynamic gestures (right) and mapping to 10 application commands.

By incorporating the user in the design phase of such an interface it could be defined and parametrized in the optimal way. The participatory design in the actual case came up with an *Email client* as the application of choice, with *6 static poses/dynamic gestures* to control *10 application functions* (Figure 1). The static pose indicated as "A" is the so-called trigger gesture to start/stop the recognition process and should achieve close to 100% recognition rate. (Alternatively, a button integrated into the top face of the gearshift could be used to activate the system.) The restriction to six gestures follows the recommendation by [3], who found out that around 6 options can be recalled without causing confusion or deviation from the main task. For details in the selection/mapping process we refer to [5].

1.1.2 Distinction from related approaches

We want to emphasize that the approach discussed and followed in this work is different from earlier (vehicular) gestural interfaces in the way that neither the full interaction range (spatially confined by the movement of shoulder, arm, hand, finger) [6] nor complex hand-forearm poses in 3D [2] are used, but only short and restricted hand poses and gestures (*movements*) in a confined space with stationary position of the hand at the gearshift. In addition, the approach followed here is based on few depth (RBGD) images and not on a continuous stream of full color video [7].

2. GESTURE RECOGNITION PROTOTYPE

The aim of this work is to show the usability of natural hand gestures for interaction with standard applications in a vehicle while driving. Therefore, a C++/QT/OpenCV application was developed, offering functions for defining, refining and mapping gestures to in-car functions and to conduct user experiments to study its performance for application control. For realtime gesture recognition three dimensional depth images provided from a *Kinect* are preprocessed with the publicly available NUI driver package and fed into the main application. According to the setting (Email client control) and the predefinitions made before (natural hand poses/gestures in the gearshift area, highway driving, driving safety not violated) we do not expect much difference in results between on-the-road experimentation and testing the system offline with applied dual task to simulate the workload while driving. Experiments were performed in a BMW 1 parked in a garage (to ensure constant light conditions as the RGBD camera is susceptible to direct sunlight) and with the *Kinect* mounted on the ceiling of the car facing toward the gearshift area.

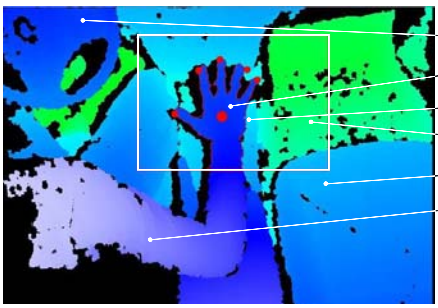

Figure 2: Experimental setting in the car with trigger gesture (all fingers outstretched) recognized.

User study and initial findings

A first study was conducted with 9 volunteers ($\overline{age} = 33.9 \pm 13.5$), whereof 3 persons stated to have already experience with the *Kinect* as controller. After calibration and short practice, test persons were asked to take the gearshift lever, to return to this position after performing each pose/gesture, and to keep the eyes during the experiment on the road (Figure 2). The request to perform a certain gesture was given on a visual display mounted on the dashboard and in the direct FOV of the driver. In total 50 hand poses/gestures had to be completed per test person (quasi random distribution of 10 gestures repeated 5 times each), once in single task and again under dual task condition using a auditory stimulus, cognitive/vocal response load as primary task.

In general, static hand poses achieved a higher detection rate than dynamic gestures (0.90/0.91 versus 0.66/0.68; single/dual task). The time until a gesture was recognized is, not surprisingly, lower for static hand poses as compared to dynamic ones. Within the two classes (static, dynamic) no obvious trends concerning recognition rate or detection time are observable. When looking on the average detection times of the two test series under single and dual task condition, it can be realized that it is higher by 9.8% under dual task as compared to single task condition.

3. CONCLUSION

In this work we have introduced a gestural interface processing static hand poses and dynamic gestures gathered in real time from the gearshift area using a RGBD camera (*Kinect*). Recognized gestures were used to control in-car applications while driving. Oral interviews discovered that volunteers liked this natural and intuitive type of interface, and that they would like to see it in future vehicles.

The following issues will be considered in the near future.

- Comparison of the gestural interface with conventional user interfaces based on button-/knob-control or speech input.
- Replication of the tests under (more) real workload conditions, e. g., in a on-the-road driving scenario.
- Continuation with customizable gestures (i. e., defined on a driver's personal preference) to achieve higher recognition rates and lower detection times.

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3D Theremin: A Novel Approach for Convenient "Point and Click"-Interactions in Vehicles

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ABSTRACT

Efficient and intuitive interaction with screens is a topic of ever increasing importance. The same applies for the car domain, where (i) navigation systems use large screens to provide information, (ii) traditional instrument boards are more and more replaced with fully configurable digital screens, and (iii) novel visual information systems such as the head-up display (HUD) find its way into.

Capacitive proximity sensing has been identified as promising technique to cope with the lack of support for screen content adaptation by proposing eyes-free, contactless human-system interaction in a mouse-like manner. While input with a single or dual dimensional capacitive proximity sensing device has been successfully demonstrated, the extension of the same paradigm to support "point & click" operations in 3D is a novelty discussed in this work.

Categories and Subject Descriptors

H [**Information Systems**]: H.5 Information Interfaces and Presentation—*H.5.2 User Interfaces*; B [**Hardware**]: B.4 Input/Output and Data Communications—*B.4.2 Input/Output Devices*

Keywords

Point & click interaction, Intuitive input, Eyes-free operation, Capacitive proximity sensing

1. NATURAL USER INTERACTION

Natural inspired interaction has recently evolved and some approaches toward this research direction have already been proposed and discussed. Currently established interfaces of this type are operating for example on (i) voice commands, (ii) viewing direction (gaze), (iii) static/dynamic gestures extracted from RGB images or depth video streams, or (iv) sitting posters recognized with pressure sensors integrated into the seating. Each of these solutions shows great potential in certain, restricted situations, but reveals major drawbacks on general use.

1.1 Finger/hand tracking using "theremins"

Capacitive proximity sensing (the "theremin" was the first musical instrument operating on this principle, i. e., was played without being touched) allows for eyes-free and contactless user interaction and is independent from interfering light conditions (darkness, sunlight) or a constrictive soundscape. We anticipate lot of potential of this technology for in-car application. Actually, input devices adopting this principle, for example by tracking finger/hand movements in front of the antennae, have been shown recently. [1] used a one-dimensional version of a theremin in a vehicular environment to study micro-gesture recognition in the steering wheel area and achieved recognition rates of up to 64% in an alphabet of ten gestures. A 2-dimensional theremin was used by [3] to study implicit, natural mouse cursor control in an office environment, and this approach was later extended to the automotive domain by sticking a dual axis theremin onto the gearshift [2]. The input device was used by the pointer finger for mouse-like control of the cursor on a in-car screen. The system achieved good performance in the single task baseline experiment, and showed only little drop in performance under dual task condition.

Device	Intercept a	Slope b	IP
-	*ms*	*ms/bit*	*bits/sec.*
Joystick (worst)	-560	919	1.1
Touchpad (worst)	-194	606	1.6
Theremin (dual task)	**75**	**630**	**1.45**
Theremin (single t.)	**220**	**410**	**1.69**
Mouse (worst)	108	392	2.6
Mouse (best)	1,030	96	10.4
Joystick (best)	-303	199	5.0
Touchpad (best)	181	434	2.3

Table 1: Index of performance (IP) of the dual axis theremin (point only) in comparison to other input devices (point & click), taken from [2].

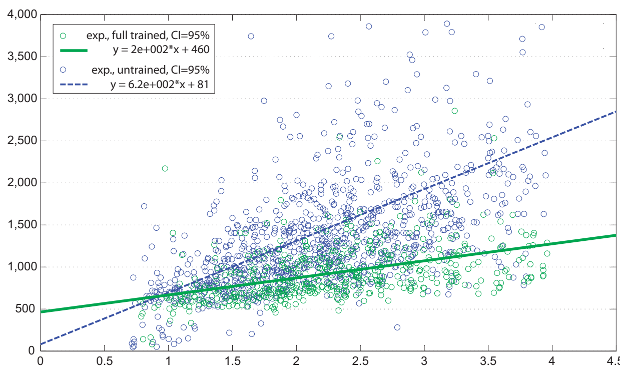

Figure 1: Significant rise in Fitt's law performance after a short training sesssion.

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To summarize, "theremins" are suitable devices for implicit input, but a few points have to be considered before their universal and successful application. A dual axis theremin covers a single plane only. Therefore, "point" actions can be reliably tracked but not the common (also in the car needed) "point & click" commands, so that it is recommended to extend the interface to a 3-dimensional setting. Unfortunately, the evaluation or comparison of a 2D setting (Table 1) is biased and cannot be taken as approximation for performance in 3D (i. e., "point & click" application) due to several reasons discussed below. In addition, supported by [3], training has been shown to lead to a significant improved interaction performance (Figure 1), and as a consequence, 3D performance shall be measured with experienced users after some time of training to get close-to-reality, representative results.

2. 3D THEREMIN: A FIRST PROTOTYPE

Revisiting related approaches and taking all the findings into account, we came up with a proposal for a 3D theremin (Figure 2) to allow convenient "point & click" functionality similar to the "mouse move, press button" paradigm. Similar forms of interaction, such as "click & zoom" (e. g., for route navigation), can be easily integrated and provided. The 3D theremin is an extension of our earlier 2D version, adding a third antenna (z axis) orthogonal to the (x, y) plane. As we used standard theremins (type PAiA 9505) as underlying hardware, adding a third dimension (antennae) implies to add a second theremin device, with finally four antennae available. In order to better represent the aspect ratio of the common 16:9 screen format in the input space, the remaining fourth antennae was used to extend the range in x axis (one "pointing" to the left, the second to the right). In the current prototype, x and y axis were used for position estimation (*point*), and the z axis, i. e, depth information, was evaluated with respect to *click* actions.

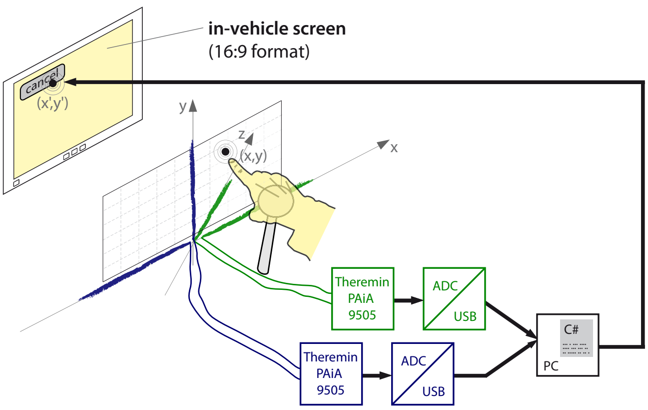

Figure 2: Proximity sensing in 3D: 2 theremin devices, 4 antennae, and extended range in x axis.

2.1 Discussion and further work

First tests with the 3D capacitive proximity sensing device gives hope for reasonable application after applying some modifications and/or extensions. We would like to take advantage of the poster presentation to discuss the open problems with experts in the field of automotive UI design. The most influential technical issues to indicate are

- Interference between the 2 theremins/4 antennae (Figure 2), in particular filtering of "double coordinates" near the point of origin $(0, 0, z)$,
- Optimization of click detection (i. e., adaptation of time window size and coordinate differences in z axis),
- Dynamic recalibration to stabilize cursor position on the screen (as movements across the z axis would cause deviations in x, y sensor values).

Beside these implementation centered problems, some user experience related issues calls for solutions as well.

- Location of the interface in the vehicle (gearshift, steering wheel, dashboard area),
- (Long term) influence of the interaction with the theremin interface on driver's cognitive load (a computer mouse maybe used all day long, but what's about gestural interaction?),
- Capability of pattern recognition techniques (applied to frequent gestures) to improve recognition rate and overall system stability.

Previous experience showed that "point & click" behavior is much better than point only, but also does not cover the full range of possible interaction or input requirements. To address this limitation, the current prototype should be extended and tested with other common tasks such as, for example, the "visual information-seeking mantra" [4]).

3. CONCLUSION

In this work we have shown initial steps toward a novel three dimensional capacitive proximity sensing device able to support common human-system interaction paradigms such as "point & click" or "click & zoom". Successful implementation and transfer of the 3D theremin into the car would open a wide field of possibilities to revolutionize traditional driver-vehicle interaction.

3.1 Acknowledgments

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Open Car User Experience Lab: A Practical Approach to Evaluating Car HMIs Holistically

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ABSTRACT

Multifunctional human machine interfaces have pervaded modern cars in the last decade. Following user centered design traditions, these interactive systems need to be evaluated in all stages of development. This requires evaluation approaches, which take the multiple facets of these systems in a dynamic context into account. This work presents the "Open Car User Experience Lab" approach for evaluating modern in-car HMIs by combining expert and user based evaluation methods. The poster introduces the system aspects, which have to be investigated, the methods to do so and finally describes an example study in which the approach is used.

Keywords

Automotive User Interface, Evaluation, User Experience

1. INTRODUCTION

A positive trend in automotive HMI (human machine interfaces) is the ongoing development of systems, which combine tertiary car functionality in a central location. As in all areas of human machine interaction, those interfaces undergo a constant stream of development, deployment and redesign for a next car generation. Most studies in the development of in car HMIs are studies in a laboratory. We nevertheless argue that field studies are necessary to raise the level of realism and to take the influence of the usage context into account. This poster contributes to HMI development by showing a way to evaluate state-of-the-art in car interfaces from a user centered perspective, using a reasonable amount of resources while still gaining sufficient information for a design iteration of these systems. Therefore, we introduce the so-called Open Car UX Lab approach, being a compromise between a controlled laboratory experiment and a long term field study. The name also indicates the independency of the approach from car manufacturers, allowing a neutral evaluation of multifunctional HMIs in the car.

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2. APPROACH

In current HCI research, expert and user based evaluation approaches are often seen as being alternating, with an expert evaluation in the early stage and a user based study with the system in a later stage of development. We nevertheless argue that both expert and user based approaches can be used beside each other, especially when an in-car interface is supposed to be evaluated holistically, i.e. taking aspects of system, user and context into account. Therefore we decided to combine both expert and user based approaches and match them to research foci, which are expected to be suited for either one of the approaches. Experts mainly investigate basic ergonomic aspects of the system, which can be rated using guidelines or which can not be investigated with users in a reasonable amount of time during a task based evaluation. The user focus, on the other hand, lays on distraction, effectiveness, efficiency and user experience. Especially, the experience related measures have to be conducted together with users and are very hard to be evaluated by experts, whose potential to empathize with users is limited.

In order to evaluate a system it is necessary to define, which aspects of the system are under investigation. For that purpose, we gathered a group of automotive HMI experts (with backgrounds in psychology, computer science and design), who developed a list of foci, based on a review of related literature (in random order):

A Accessibility / Ergonomics of input elements. This refers to how well interactive elements can be accessed according to aspects of ergonomics.
B Readability of displays and labels. Describes how well interactive elements can be perceived by users.
C System logic, connection of software and hardware elements. This focuses on the internal consistency and other aspects of a menu design, which influence the human machine interaction.
D Usability (efficiency and effectiveness). Effectiveness refers to the successful completion of a task and the quality of the system in supporting the user to do so. Efficiency describes how much resources have to be invested in order to complete a task, in the case of our approach it refers to the time needed to complete a task.
E Distraction caused by the system usage. In automotive HMI, distraction caused by a system is often seen as time spent not looking at the road but at a certain interface element.

F User Experience (Perceived Workload, Trust, Acceptance, Hedonic and Pragmatic Qualities). User Experience (UX) is the entire set of effects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning), and the feelings and emotions that are elicited (emotional experience) [3]. In order to reduce complexity, we propose to focus on certain factors of UX, which are considered highly relevant for in-car interfaces.
G Qualities of the systems under dynamic contextual influences, such as lighting conditions. When interacting with an automotive HMI, the context of use is highly dynamic, especially in terms of the surrounding environment.

2.1 Expert Evaluation

The Open Car UX Lab includes the application of an expert based approach using guidelines, investigating the research foci A, B, C and G, as introduced above. The expert evaluation is based on the heuristic evaluation of Nielsen [5]. As guidelines we developed the Open Car UX Lab guidelines, which are inspired by established interface guidelines, like the SAE safety guidelines [6], the heuristics introduced by Nielsen and the human factors guidelines by Green et al. [1]. Each guideline consists of a main headline, a description and sub guidelines. Due to space limitations, the Open Car UX Lab guidelines can not be included in this paper, but will be introduced on the poster, the full set can also be obtained through the authors.

2.2 User Based Evaluation

As mentioned before, thelater user part of the Open Car UX Lab focusses on the topics D, E, and F, as introduced above. For that purpose, participants are invited to try out and conduct tasks with the centralized tertiary in-car system. We identified four main groups of functions: Navigation, Entertainment, Communication and Configuration. Since most current systems group functions accordingly, example tasks from each functional group were selected. The tasks were chosen since they represent a typical feature of each functional group and are therefore available in all modern in car systems. We additionally analyzed the tasks to identify, if they were designed to be conducted while driving or while parking the car. The result of this analysis was reflected in the study approach, so that users conduct a set of tasks while parking and a set while driving. We finally identified five tasks, which exemplify this approach:
T1: Enter navigation destination (park)
T2: Stop navigation (drive)
T3: Select radio station (drive)
T4: Call number from address book (drive)
T5: Change fader setting (drive)

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. In order to analyze the distraction caused by the system usage, a head or car mounted eyetracker and corresponding markers (for the head mounted system) are used. Apart from the measurements regarding task duration, success and eyetracking, User Experience is in the focus of the study. For that purpose, UX questionnaires are handed to each participant after finishing the tasks, for example the trust questionnaire by Jian at al. [4]; the NASA TLX or RTLX to measure perceived workload and the AttrakDiff questionnaire [2] for perceived hedonic & pragmatic quality.

3. EXAMPLE STUDY

We applied the approach in an example study, comparing the Audi MMI, the BMW iDrive and the Mercedes COMAND systems. Within our sample (6 male, 6 female), we found high differences in the mean task duration, tasks conducted with the BMW system took on average 51.16s (SD: 29.1), while the tasks with the Audi MMI required 65,98s (SD: 39,7), resulting in tasks with the BMW iDrive only requiring 72% of the task duration required for Audi. Especially remarkable were the differences in the radio task (Audi: 43.22s [SD: 66]; BMW: 25.93s [SD: 25.4]) and in the phone task (Audi: 55.22s [SD: 28.4] ; BMW: 35.14s [SD: 22.9]). The eyetracking data showed a high level of distraction caused by all systems. Combining gaze percentage and task duration, the BMW iDrive led to the lowest overall distraction from the road, followed by the Mercedes and Audi systems. On the other hand, the Audi system got the highest ratings in terms of attractiveness.

In this poster we present the Open Car User Experience Lab approach. Improvement potential for the future lays in the redesign of the expert guidelines towards a well defined heuristic and a computer supported guideline assessment tool. Results showed that user interface flaws were identified more often with some guidelines than with others. We plan to address this by adding more detail to the often used guidelines and potentially dividing them. Less used guidelines may be summarized in the future to limit the number of guidelines.

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Situation-adaptive driver assistance systems for safe lane change via inferring driver intent

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ABSTRACT
This paper focuses on driver intent inference by investigating driver glance behavior and driving maneuver, and attempts to show a general framework to design a situation-adaptive driver assistance system for avoiding a crash or an incident. The results show that inferring driver intent via monitoring driver glance behavior is not only to comprehend driver intent, but also important to detect if the driving performance is safe. The study revealed how to apply the intent inference for providing an appropriate support at a proper time point, which is expected to improve driver's acceptance and driving safety.

Keywords
Situation-adaptive automation, driver intent, safety, glance behavior

1. INTRODUCTION
National Highway Traffic Safety Administration (NHTSA) has shown that approximately 25% of crashes were attributed to driver distraction [1]. Furthermore, many transportation researchers revealed that drivers' recognition failure accounted for 65-75% of the lane changing/merging crashes, in which drivers failed to be aware of traffic environment around, or initiated changing lanes without recognizing a vehicle driving in a blind spot [2]. For the recent decades, several intelligent driver assistance systems have been developed for preventing such a distraction-related crash. Those functions can be classified into different types: (1) caution type support functions for enhancing driver's situation awareness [3], e.g., Blind Spot Information System (BLIS), (2) warning type support functions for aiding driver's decision making, e.g., Lane Change/Merge Warning systems, (3) and action type of support function for assisting driver's operation.
As many types of advanced drive assistance systems are developed, the selection of an appropriate system is becoming an important issue to be addressed [4]. Inagaki points out that it is necessary to take "who should do what and when" into account [5]. Thus, it is claimed that it is necessary to develop a situation-adaptive automation, which trades the authority of control in a dynamic manner. That is to comprehension driver's intent creation before an initiation of driver's maneuver.
The purpose of this study is to investigate how to develop a situation-adaptive driver assistance system for changing lanes based on an inference of driver intent.

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2. Driver's lane-change intent
2.1 Driver glance behavior
Zhou, Itoh, and Inagaki [6] investigated driver's glance behavior on the side-view mirror for preparing lane-change. The result showed that the glance behavior increased significantly once a driver created an intent to change lanes. Based on this finding, an algorithm for inferring the driver lane change intent was developed. In the algorithm, four levels of driver lane change intent were distinguished:

- EXTREMELY LOW: A driver has not recognized a slower lead vehicle or has not decided to pass the lead at all;
- LOW: He/she has decided to pass the lead vehicle;
- MIDDLE: He/she decided to pass the lead vehicle, but not determine to change lanes yet,
- HIGH: He/she determined to change lanes once the traffic conditions allow an implementation,

Based on the frequency, say N, of driver glance behavior to look at the side-view mirror within the last 12 seconds, the driver lane change intent was regarded as LOW when $0 < N \leq 1$, as MIDDLE when $1 < N \leq 3$ and HIGH when $N \geq 4$.

2.2 Distracted driver's lane-changing intent
Zhou et al. [7] also investigated driver's glance behavior under cognitively distracted situations. Driver glance behaviors were collected and analyzed under the two conditions: driving without secondary cognitive task and driving with a secondary cognitive task. As the distracting secondary task, a secondary task of "Telling a story" task was given to the participants. During driving, drivers were asked to make a short story with using the four key-words from a speaker connected with a PC, and to tell the story for at least 50 seconds during preparation of the lane change. The result showed significant decrease of the glance behavior frequency under the condition of driving with the secondary task. Based on the comparison of driver's glance behavior under the two conditions, Zhou, et al. claimed that there existed two types of inappropriate lane-changing intent creation under the distracted-driving condition. One is the delay in intent creation (Figure 1(a)), where the lane change was done lately, and

the other is incompleteness of the intent creation (Figure 1 (b)), where the driver failed to create the intent to change lanes.

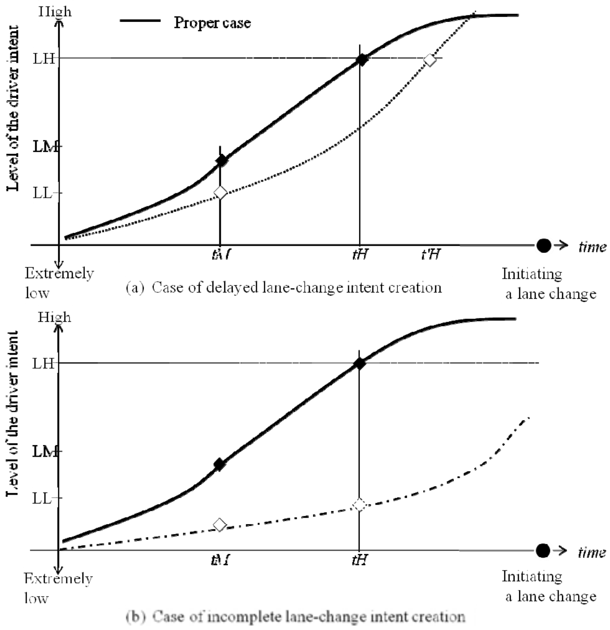

Figure 1. Two types of inappropriate intent creation under distracted-driving condition

3. Developing an adaptive driver assistance systems for safe lane change

3.1 Problems in distracted intent creation

The results of investigations on the driver glance behavior under the distracted-driving condition distinguished two types of effects on driver glance behavior. The delayed type (Figure 1(a)) might be caused by the reduction of the attention to the environment. The incomplete-type (Figure 1(b)) was that the distraction caused the failure in having the intent to change lanes rather than the degradation of drive situation awareness. Both of the two cases might increase the risk when a lane change is initiated. It is important to note here that a driver assistance function should be different for the two cases. More concretely, the caution type support function for enhancing driver's situation awareness should be suitable for the delayed case in order to re-attract the driver attention. For the incomplete case, on the other hand, a further warning support system should be needed. More concretely, a warning message for evoking the situation awareness is given when a deviation from the appropriate driver intent creation; and an action protection function becomes essential if a driver ignored or missed the warning message.

The above discussion represented that inferring driver intent was a vital role to decide which function should be given and when.

3.2 Situation-adaptive support system for safe lane change

Based on the investigations in this study, a framework of a situation-adaptive support system is developed (see Figure 2). This framework mainly consists of two parts, *inferring* driver intent and *supplying a support function*. At the inferring phase, the system processes environmental information (e.g., traffic condition), physiological information (e.g., glance behavior) and driving information (e.g., steering angle, heading), infers what a driver is going to do, and detects whether the driver is driving at a normal state and determines which level the current intent is. Once an abnormal cognitive state is detected, the system tries to judge which kind of support function should be given adapting to the detected intent level.

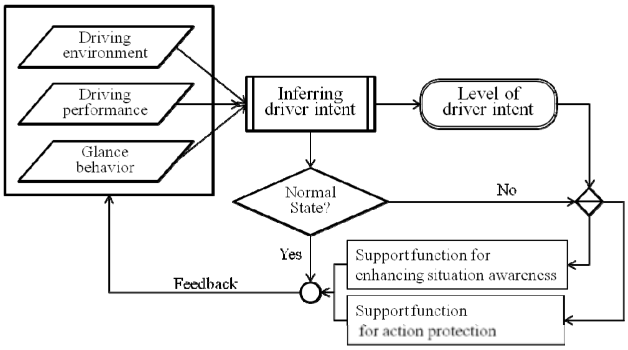

Figure 2. Supplying safety support function adapting to driver intent inference

4. Conclusion

This study presented how to apply the driver's intent inference for developing a situation-adaptive support system. The investigation implied that this adaptive function based on driver intent would be helpful to give a proper support function at a proper timing and to avoid an unnecessary support. Thus, the system will be expected to supply more comfort and effective function to a driver.

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Determination of Mobility Context using Low-Level Data

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ABSTRACT

Mobility can include a variety of transportation modes, spanning from walking over public transportation (bus, train, etc.) to driving. All these different modes have different contexts, which have unique features and different requirements to the user and his need for information. In this paper we present and evaluate some heuristics for determining the mobility context of a user based on low-level data collected using a smartphone and discuss possible applications. We identify the challenging aspects of the approach and discuss the next steps.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search Heuristic methods; I.3.6 [**Artificial Intelligence**]: Methodology and Techniques Ergonomics [user context]

1. INTRODUCTION

The users mobility context strongly affects which information is relevant for him and also how much information he can perceive without getting overwhelmed or distracted. Automatic context information could for instance help to adapt the way information is presented in a car with consideration for the cognitive load of the user. Furthermore, functionalities could be changed to suit the users need, e.g., from a schedule in a bus to a navigation system in the car. In addition, the same information could be used to give the user additional information about his mobility profile, e.g., calculating his carbon footprint or make suggestions for a more economic or ecologic use of the different transportation means.

Mobility can include a variety of transportation modes, spanning from walking over public transportation (bus, train, etc.) to driving. All these different modes have different contexts, which have unique features and different requirements to the user and his need for information.

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Figure 1: Visualization of a trace using google earth. Correct determination of transportation means is depicted in green, incorrect results depicted in red. The recognition of railway line in parallel to the highway is confused with driving by car.

Most of the related work is published under the broad term of human activity recognition. Thereby, the particular set of activities and target applications differ. [3], for example, address the problem from a very general point of view, proposing an ontology-based approach, which is intended to cover a broad range of activities from writing on a blackboard to riding a motorbike. In contrast to that, [4] restrict there approach to indoor moving patterns based on wireless LAN, while [1] cover outdoor activities like jogging, walking, or riding a bicycle. [2] address the recognition of transportation modes, which comes very close to what our work is targeted at. However, all mentioned studies have in common that the downstream application is adaptation of the mobile application itself, mostly formulated rather vague as "optimization of the mobile device behavior". We intend to learn human activity in order to predict future activity (transportation needs).

2. OUR APPROACH

In order to make our context recognition as flexible and universally usable as possible, we decided to only use low-level GPS data which are provided by every smartphone or navigation system. During our series of tests, we used Android powered smartphones with a simple logging app, which writes every GPS-data change in a plain text file. Bases on these information, we attempt recognize the users mobility context.

We recorded 25 traces with up to 45,000 individual mea-

Figure 2: Visualization of a trace with afoot parts. Incorrect (red) results are caused by inaccuracy of the GPS signal.

Figure 3: Visualization of a trip on the highway. Red parts are caused by traffic jams which are confused with walking.

suring points each. 10 data sets were used to develop the heuristics, 15 for cross validation. The traces were recorded in everyday situations, using car, train or walking. The raw data was converted into an XML format for further processing. The measured positions were clustered in sections of approx. 30 meters length.

We use some heuristics (see Algorithm 1) based on speed and acceleration values obtained from GPS positions in order to determine the current mobility context based on the sensor data.

3. EVALUATION

To evaluate the heuristics, we applied them to our cross validation data sets.

We identified some areas with suboptimal recognition rates, especially confusing train rides with riding a car (Figure 1). The routing and the speed of a train is too similar to a car to be distinguished using the low level GPS data on which our heuristics are based.

Furthermore, the recognition of walking is challenged by the inherent inaccuracy of the GPS signal (Figure 2). In our annotated data we have found walking speed up to 30 km/h. Another problem was encountered in connection with loss of the GPS signal, e.g., when entering a building.

Algorithm 1 Heuristic for determining mobility context

```
for allSection do
  {speed infos}
  if thisSection.speed > 120 then
    thisSection.carProb(+0.8)
    thisSection.trainProb(+0.2)
    thisSection.afootProb(-1.0)
  else if thisSection.speed > 50 then
    thisSection.carProb(+0.5)
    thisSection.trainProb(+0.5)
    thisSection.afootProb(-1.0)
  else if thisSection.speed > 10 then
    thisSection.carProb(+0.5)
    thisSection.trainProb(+0.5)
    thisSection.afootProb(-1.0)
  else
    thisSection.carProb(0.0)
    thisSection.trainProb(0.0)
    thisSection.afootProb(+0.5)
  end if
  {future context}
  for next20Sections do
    if (accelerateToMoreThan120) then
      thisSection.carProb(+0.8)
      thisSection.trainProb(+0.2)
      thisSection.afootProb(-1.0)
      break
    end if
  end for
  if (accelerateToMoreThan10) then
    thisSection.carProb(+0.5)
    thisSection.trainProb(+0.5)
    thisSection.afootProb(-0.2)
    break
  end if
end for
```

Another challenge we discovered is the recognition of traffic jams (Figure 3). Under some special constellations of speeds, length and other parameters a traffic jam could be detected as a walk.

4. CONCLUSION AND OUTLOOK

The use of low level GPS data as only source is not sufficient for recognizing the mobility context of a user. As an additional challenge, the current heuristics are looking ahead in the data stream which is not feasible for immediate context determination.
It is necessary to connect the low level data with other information, such as street maps, schedules or additional sensor data (e.g., accelerometer) to obtain more reliable results.

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Addressing Road Rage: The Effect of Social Awareness in Every Day Traffic Situations – A User Study

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ABSTRACT

This paper addresses the effect of social awareness on road rage in everyday driving situations. In the user study we conducted subjects experienced three everyday traffic situations. They where either enriched by information about the driver in front or no information was presented. The subject's interaction with the system was limited to angry comments, honking or showing a happy face. We found an effect of presentation condition on the reaction type: When displaying information that matched subject's personal preferences, more friendly reactions were observed than in the other conditions. The results of this study serve as a basis for a large-scale study in a social network.

Categories and Subject Descriptors

H.5.2 [**Information interfaces and presentation**]: User Interfaces, User-centered design

1. INTRODUCTION

Online social networks have become common in the past few years and are broadly accepted today. These networks link people with a "spiritual" proximity but do not consider the "physical" proximity. When the internet got available on todays common smartphones, the social community also got mobile. These ad-hoc communities are the latest developments: Google latitude [2] for example brings together people with same interest and currently being at the same place, therefore overcoming this specific limitation of traditional online social networks. Millions of car drivers who share the same road every day also form a social community. Even though, in contrast to traditional social networks, they share the same "physical" proximity they lack the ability of communicating with each other hence are not able to share their "spiritual" proximity. As a consequence, time pressure and anonymity often cause yelling, shouting and honking (often referred to as "road rage"). The extension to ad-hoc social road communities is at hand since the technical foundations are opening communication channels to each other and current research in the domain of vehicular ad-hoc networks is focusing this topic [1]. While current use-cases are mostly safety related and therefore not addressing anonymity while driving, the underlying technology could easily be used for transferring other data such as social information. Linking together this technology and already existing social networks would significantly decrease the level of anonymity while driving. Decreased anonymity in traffic situations in turn affects road rage as previous studies have shown [3] [4].

In this paper, we examine the effect of social awareness in every day driving situations on road rage. We therefore conducted a user study and presented three distinctive driving situations. The scene was enriched by information about the driver in front which either matched a subject's personal preference or was unrelated to her likings. In a third condition, we showed no additional information at all. The presented scenes slowed down the participant's car and conflicted with the primary goal of reaching the destination within a given time-frame. We limited the possible interactions in these situations to either honk, yell or show a happy face. Our Hypothesis was that realizing the car driver in front has something in common with the own preferences leads to a more friendly reaction. It was further hypothesized that presenting irrelevant or no message provokes a more aggressive reaction. The results of this paper serve as a basis for a large scale experiment in which we will distribute the system as a game in a social network thus reaching a large number of people.

2. EXPERIMENTAL STUDY

Subjects. 18 subjects (6 female, 12 male) participated in this experiment. The age range was 19 – 40 years with an average of 26 years. All subjects possessed a valid driver's license and were registered on facebook. Note, that facebook requires the user to explicitly confirm that the added application may use personal data.

Apparatus. The experiment was conducted in a lab in front of a standard PC. The participants were presented a simulated driving scene which is exemplified in Figure 1, upper left image. The only possible interaction with the system (and therefore taking influence on the scene) was to hit one of the buttons on the bottom (from left to right): *AngryComments*, *Honk* and *HappyFace* which indicated a communication with the driver in front. *AngryComments* and *Honk* were supposed to be negative reactions while *HappyFace* was considered to be positive. An appropriate sound was played when the subject interacted with the buttons. At the beginning of the experiment the car accelerated automatically to 60 kilometers per hour and kept a constant speed. A speed indicator was present on the display on the upper right during the whole experiment as well as a driving sound. The primary goal was to reach the destination within a given time frame indicated by a countdown timer on the upper left of the display.

Procedure. The whole experiment lasted for about 10 minutes. Before the experiment started, information was given in written form explaining the course of the task, the user interface and the different scenes. After that, the participant was asked to log in to her/his facebook account and to add our application. After

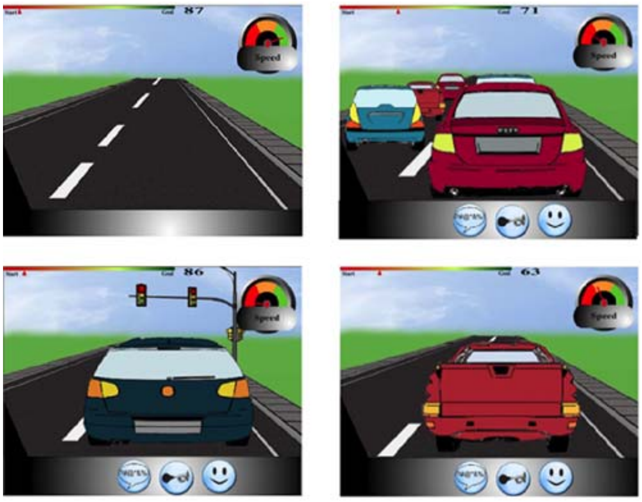

Figure 1: The displayed scenes. From left to right, top to bottom: Initial scene, *TrafficJam*, *TrafficLight*, *SlowCar*

driving 10 seconds on an empty road at full speed (Figure 1, top left), one of the other scenes slowed down the subjects' car.
During the experiment, we presented three different scenes, namely *TrafficJam*, *TrafficLight* and *SlowCar* (Figure 1). In the first scene the car drives into a traffic jam and gets stuck. The second scene shows a red traffic light and a car in front. After the traffic light turns green the other car ignores the green light and therefore blocking the street. In the third scene the participants' car is slowed down by an upcoming car. After any interaction with one of the buttons in the individual scene, the cars started moving or speeding up again respectively. Each scene occurred twice resulting in presentation of 6 scenes in total in each run.
There were three different conditions of message presentation (*NO_MSG*, *REL_MSG* or *IREL_MSG*). In the first case no additional information is presented. In the other conditions information about the driver in front is used: *REL_MSG* adds information to the scene where the participant most certainly has a preference for, e.g. "The driver in front also studies at Saarland University". This information was retrieved using data from her facebook page. *IREL_MSG* uses information which the subject has no preference for, e.g. "The user in front is born on 24/03/82".
The order of the presented scenes was fixed but the order of appearance of *NO_MSG*, *REL_MSG* and *IREL_MSG* between subjects was counterbalanced. Only two presented messages contained personal information, the remaining 4 were either of class *NO_MSG* or *IREL_MSG*. It was never the case that two messages of class *REL_MSG* were presented in a row. The first message presented was always an irrelevant message (*IREL_MSG*). The experiment ended by either indicating that the goal was reached in time or a failure message in case the time was up.

3. RESULTS

Figure 2 shows the results over all participants in conditions *NO_MSG* and *IREL_MSG* and *REL_MSG*. When no message is presented (condition *NO_MSG*) we could confirm our hypothesis of more frequent aggressive driver reactions. For presenting general messages which do not match to the personal preferences of the participants according to their social network profile, we could observe similar results. For the presentation of messages which match personal preferences of the participants, we observed a shift from *AngryComments* and *Honk* to *HappyFace*. Due to nominal scaled data, we used a Chi-squared test to check wether our results are statistically significant. We aggregated *AngryComments* and *Honk* as negative reactions and *HappyFace* was the positive reaction. For condition *REL_MSG* subjects more often reacted in a friendly way in comparison to condition *IREL_MSG* ($\chi 2(1) = 8.10, p < .01$) and also in condition *NO_MSG* ($\chi 2(1) = 7.65, p < .01$). This confirms our initial hypothesis: When matching personal preferences about the driver in front are presented, a more friendly reaction can be observed.

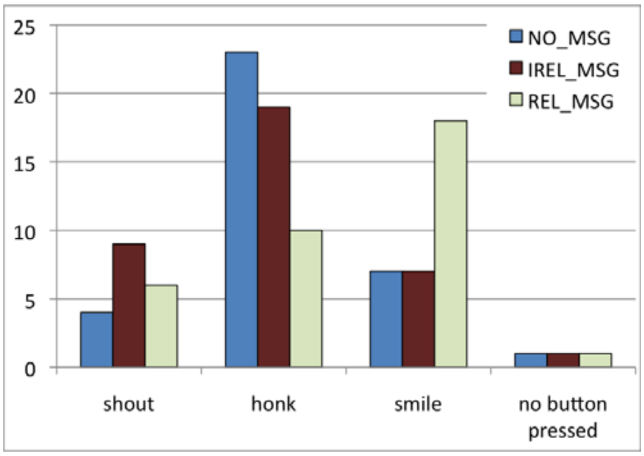

Figure 2: Frequency of reactions in conditions *NO_MSG*, *IREL_MSG* and *REL_MSG*. We measured significantly more button presses to *HappyFace* in condition *REL_MSG* over conditions *NO_MSG* and *IREL_MSG*.

4. CONCLUSION & FUTURE WORK

This paper presented a user study which investigated the effect of social awareness on road rage in three driving situations. We measured the reaction of participants when altering the situation in terms of messages with or without personal information about the car driver in front or no message at all. We used data available from the subject's social network page since asking obvious questions in advance would compromise the results. When presenting irrelevant messages or no message at all a more aggressive reaction could be observed (compared to when presenting relevant messages). A more friendly reaction could be observed when using the subject's personal preferences according to her facebook page. These results indicate that spiritual proximity has a positive effect on the driver's interactive behavior in cases of physical proximity. They also indicate that already existing information in social networks can be used to realize matching personal preferences. In order to confirm our results, a follow-up study with the results of this paper will be conducted. We will then distribute the system as a game in a large social network hence reaching a larger number of people. These results will influence design and implementation of an in-car social networking application on the basis of V2X.

5. ACKNOWLEDGMENTS

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New Apps, New Challenges:
Quality Matters in Automotive HMI Development

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ABSTRACT

Integrated testing of external applications, that are not known to the automotive HMI at design time, is not possible. We approach this issue with universal pre-tested GUI components to encapsulate possible data flow, widgets, their property values and screen states. Based on an abstract user interface model the HMI software maps the respective elements to pre-tested compositions of these GUI components. By this, a more dynamic automotive HMI development can be achieved building the basis for error-free HMI generation processes from external applications at runtime. We analyze the development steps based on an application example. The results contribute to further development of standards and best practices for HMI modeling languages, HMI generation and model-based testing.

Categories and Subject Descriptors

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

1. INTRODUCTION

With the increasing spread of powerful smartphones and a large-scale availability of high-speed internet individual applications and data are available almost anywhere and anytime. This trend also affects infotainment systems in cars. Customers desire a convenient integration of different external devices and services in the in-car environment. Assuring the quality of previously unknown applications and data is a challenge since it is not possible to test those applications connected to the in-car infotainment system at design time of the car head unit (HU). An integrated test of all published applications connected to the existing automotive human-machine interface (HMI) is not feasible. We address this issue by the definition of pre-tested components and combinations of these. We use the example of a basic *Facebook*[1] application. The user brings their smartphone with the application running into the car and connects it to the HU. The application provides access to the user's *Wall*, their *Info* site and the possibility to create a new *Status* message. Based on a defined application description a user interface is generated by the HU software. Figure 1 illustrates a possible generated graphical user interface (GUI)

[1]Facebook: `http://www.facebook.com`

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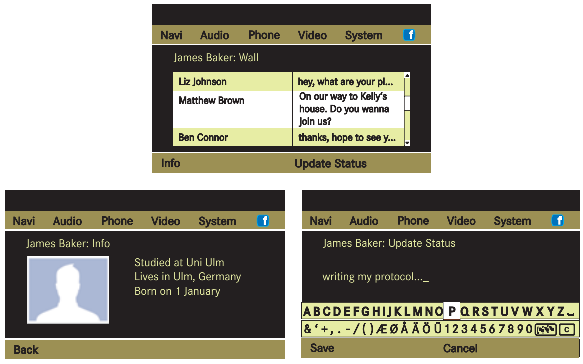

Figure 1: External Facebook application generated in a Mercedes-Benz HMI

for an existing Mercedes-Benz HMI concept. The GUI consists of a main menu (MME) where all available applications can be accessed, e.g. Navi or Audio, and respective application areas. Each application consists of an application field (AFL) where the actual content is displayed and a sub menu (SME) for content specific options. The HMI is operated via a central control element (CCE) allowing the driver to set the selection focus by turning the CCE or pushing it in one of eight directions (N,NE,E,SE,S,SW,W,NW) and activate options by pushing it down.

2. BACKGROUND

Model-based development using a respective modeling language holds the advantages of reusability, readability and easier adaptability of user interfaces (UI) amongst others [2][1]. Several approaches for defining a UI model exist (e.g. [4] [7]) that focus on continuous model-based processes for UI development. In our context we need to extend a model-based UI description with rules for integrating the UI into an existing strictly defined HMI concept. Several researchers use model-based approaches also for HMI testing (e.g. [6] [8]). However, they focus on testing existing HMIs. We need to apply model-based testing for previously unknown user interface parts that are integrated into an existing HMI. Memon et al. [3] transfer the principle of unit tests to the area of UI testing. They motivate the use of independent UI units for graphical user interfaces, so called *GUI components*, to reduce complexity of tests. A *GUI component* constrains the interaction focus of the user within the com-

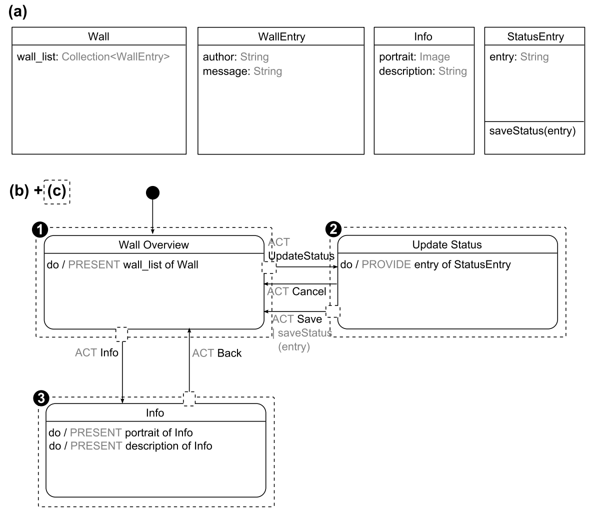

Figure 2: Abstract UI model of the Facebook application: (a) Functional application interface, (b) Abstract interaction model, (c) GUI components

ponent when it is called. The last user action within the component leads to its termination. The composition of several *GUI components* concerning their invoke behavior is achieved with an *integration tree*. This form of modeling allows separate testing of the individual components and their invoke behavior. Thus, for the generic testing approach universal *GUI components* and a universal *integration tree* have to be specified and tested in advance to ensure an error-free generated user interface.

3. APPROACH

We applied the concept of *GUI components* to combine UI screen elements, so called widgets, in order to define universal modules which can be mapped to the abstract UI model elements of unknown applications. For the example *Facebook* application the abstract UI model is illustrated in figure 2 consisting of the functional application interface (a) and the abstract interaction model (b). In current research these abstract elements are used at runtime to transform them to combinations of respective HMI widgets on the target system [5]. We adapt this to pre-tested combinations of strictly defined *GUI components* in order to fulfill HMI testing requirements. Each interaction state in the UI model is the basis for a component. For the HMI concept given in figure 1 the target components are structured into application field (AFL) and sub menu (SME). Generic *GUI components* were identified in our example to support the functionality required by the *Facebook* application. Figure 2 (c) illustrates the three components (1,2,3) based on the abstract interaction model. A result of the *GUI component* definition is a list of widgets and value ranges for their critical properties. Properties are critical concerning HMI testing when they affect their size as an example. In total, we identified more than 30 critical properties in 7 widgets for the example scenario. In order to ensure the stability of the *GUI components*, those widgets have to be tested and approved for the given ranges of property values. Finally, all possible sequences of components have to be applied in order to test the *integration tree*. Since *GUI components* are encapsulated concerning interaction logic and data flow, we only need to analyze each transition separately. This means, each component has to invoke every component at least once.

4. CONCLUSION AND FUTURE WORK

We illustrated the need to define and test *GUI components* derived from abstract interaction models at HU design time resulting in a universal repository of *GUI components*. Then, external applications can be integrated at HU runtime if their structure and behavior are described with defined application interfaces and abstract interaction models. This abstract application description is transformed to compositions of *GUI components* provided by the HU. Correctness of the HMI is guaranteed by this process: Either a valid combination of pre-tested *GUI components* can be found or the external application is not supported. This allows a basic but flexible integration of external applications into the automotive HMI with a model-driven approach. In future work we plan to add more dynamics to the component design and selection to increase flexibility. The results from our widget and component analysis push the development of future standards for HMI modeling languages, generation processes and model-based testing processes.

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The Ethnographic (U)Turn: Local Experiences of Automobility

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ABSTRACT
The Local Experiences of Automobility (LEAM) project creates an ethnographic design space encompassing the car, the infrastructure and the ecosystem around varied smart transportation futures. This space is informed by locality and context dependent conditions of how, when, and why cars are used, by whom, and under what conditions. In this paper we present the ethnographic methodology for a multi-country exploration of driving experiences in Brazil, China, Germany, Russia, and the United States using in car sensors such as GPS, smart phone usage applications in concert with ethnographic interviews and subject journaling.

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

General Terms
Documentation, Design, Human Factors, Theory.

Keywords
Automobility, ethnographic research, sensors, GPS,

1. INTRODUCTION: A GRINDING HALT
After 100+ years of moving faster and further with cars, we are beginning to grind to a halt. As more drivers exercise the individual freedom to move about promised by car ownership, the fruits of our "self-defeating quest for mobility" [1] surround us, from Lady Gaga and William Shatner tweeting warnings about Carmaggedeon in L.A., to 11 day, 100 km traffic jams in China, to the proliferation of regulations like São Paulo's *Rodízio* traffic control to limit cars on the road by license plate number. The dream of freedom of the road has given way to the unavoidable reality that we need to think beyond our own four wheels if we are to keep moving at all. We need to rethink what makes cars useful, what makes a useable road and radically redesign what's on our roads in tandem with our transportation infrastructures. Integrating advanced communications, services and sensors to create 'smart' cars will not be enough; such a car will only be useful in conjunction with smart roads supporting new systems for resource use, commerce, regulation, taxation and surveillance.

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A significant portion of current smart car and smart transportation development focuses on making cars do what people don't always do well: pay attention, react quickly, multi-task, and make good judgments [2]. Smarter cars are imagined as less dangerous, highly-efficient users of time/space, and personalized to the driver's foibles. For example, Google's self-driving car specifically touts increased safety, gas efficiency and the potential to put even more cars on the road (without gridlock). In its current prototype, a car drives itself, sensing and reacting to the environment, while sending queries, receiving, collecting and sharing data with Google cloud services. It is a vision that funnels our experience of mobility in the physical world through Google's cloud services.

But it's also a remarkably undifferentiated vision. If Google could start with a blank slate, the potential for rapidly building smart transportation systems would be vast. While Google had a relatively blank slate with the Internet and unencultured users – for smart transportation, they and other builders must start with 100+ years of diverse trajectories of roads, regulations, and deeply embedded local practices. While ubiquitous computing will incrementally alter how we drive in the 21st century, it cannot, and will not do so uniformly. As Dourish and Bell [3] note, ubiquitous computing is inherently messy, uneven, built as much on webs of social values as on silicon.

2. FACING EXISTING CAR EXPERIENCES HEAD ON
Building on findings from our recently completed Car Turn Outs Project [4], and agreeing with Dourish and Bell on the heterogeneity of ubiquity, we believe smart transportation will be differently realized in various markets and will need to face the complexity of existing car experiences head on. The basic mechanics of how cars are operated are, to some degree, universal. Yet cars, precisely because they are so integrated into many peoples' existence, are experienced in very localized ways depending on the natural environment, the infrastructures of roadways and traffic systems, including legal, regulatory, safety and surveillance systems, as well as the social and cultural milieus. The inclusion of advanced hardware and software in the automobile platform will create the opportunity for even more varied experiences in and around the car. Rather than isolating the user from the landscape, as Urry [5] and de Certeau [6] characterize automobility, the infusion of services and advanced communication and sensing technologies into the car will create the paradox of simultaneously more isolated and more grounded experiences of mobility; more non-location-based information,

media, content, and sociality will be present in the car, while the connections and pathways technology can enable diminish the displacement of the car, creating new locations and new experiential landscapes. The heterogeneity of automobility future experiences is at the core of our research approach. The goal of the LEAM Project is to explore the diversity of automobility experiences in Brazil, China, Germany, the United States, and Russia. The research is currently in field, but here we discuss our processes we are developing to understand the relationships among practices, cars, and technology.

2. THE ETHNOGRAPHIC (U)TURN:

Methodologically speaking, this project represents a full return to ethnographic research as practiced during the initial florescence of anthropology by scholars like Boas, Malinowski, Benedict, and Radcliffe-Brown. Ethnography in this era was characterized by an array of systematic techniques that combined quantitative and qualitative approaches. The diversity of the LEAM team: anthropologists, computer scientists, designers, and an experimental psychologist; allows us to combine disparate data types and analyses in service of multi-faceted portraits of automobility grounded in an ethnographic perspective that privileges lived experiences of mobility.

The team approached the challenge of fieldwork and analysis by employing multiple modes of data gathering, each only useful in combination with the others. One lesson learned from the CTO project is while the physical objects in the car represented traces of past behaviors and routines, as well as people's values, they were not enough to provide insight into movement, insularity vs. embeddedness in emergent social milieus, nor how the car extends into social space. Like archaeologists, we were looking for different types of traces of the past; we needed to see the things we could not see - cars in use, in movement, and located in space. We needed to render more direct, comprehensive and visible traces of the ephemerality of movement, temporality, the isolation and the embeddedness of automobility in the local landscape.

We supplement the in-depth ethnographic interviews and car turn out exercises with approximately 30 days of data from in-car light, sound, acceleration and temperature sensors, GPS tracking for routes, speeds and stops (complimented by participants logging stops and creating short videos describing their car use), and smart phone usage tracking. Each method probes on different aspects of automobility, from lived experiences of owning, using and being in a car in motion, to car use mobility patterns over time, to in-car environmental characteristic, to the interplay/tension between built-in and brought-in technologies. The data only fully comes alive when we begin to overlay the sets, and analyze the data in combination. For example, questions immediately emerged around behaviors such as, when is a stop not a stop based on the GPS data? What is routine car use? What is atypical? And how are those patterns experienced? We could not begin to answer these without also looking at the smart phone tracking data (in Brazil phone use appears to cluster around the start and finish of journeys and during very slow movement). The smart phone data shed light on the spatially-based GPS data and vice versa. Additionally, knowing that cars are deeply embedded in people's social relationships, we wanted to understand the car as a fundamentally social technology. The data collected from peoples' smart phones allowed us to understand mobility relative to sociality as well as complex social networks – multiple users, shared usage, other interdependencies but it did not provide enough insight into the social nature of cars. This required a follow-up in-depth interviews with participants armed with various visualizations of the GPS and smart phone usage data. We are currently refining representations of the data as we re-interview the respondents, using layers of maps, timelines, route, behaviors, experiences, and stops. The result is an extraordinarily rich combination of social, spatial, experiential and temporal data.

3. CONCLUSIONS

The movement and traceability of people, objects, and cars are bound up in larger social meanings and structures that are not always at the surface of lived daily experience. The LEAM project seeks to trace the outline of these relationships and provide a path forward for the meaningful infusion of technology in the car/human equation.

We believe this is necessary and important perspective if we are to build successful smart transportation solutions. Returning to some of the challenges around smart transportation solutions, self-driving cars will need to be differently realized to be successful in places like Brazil. In São Paulo drivers often leave large distances between themselves and the car in front of them at traffic lights (enabling evasive action from carjackers or thieving *Motoboys*) and they roll through stop signs and traffic lights at night to avoid stopping - another opportunity to be robbed. A self-driving car that forces complete stops at red lights at night, or "efficiently" packs cars on roads with no space between them makes no sense in urban Brazil, doing potentially more harm than good to drivers.

The LEAM project creates a design space encompassing the car and the infrastructure and ecosystem around varied smart transportation futures. This space is informed by locality and context dependent conditions of how, when, and why cars are used, by whom, and under what conditions. This research, preliminary as it is, opens a new design space for thinking about cars as part of a living network of people, places, and things in motion.

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(C)archeology -- Car Turns Outs & Automobility

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ABSTRACT
In this paper, we describe key findings from the Car Turn Outs project, Intel Corporation's Interaction and Experience Research (IXR) Lab's first exploratory ethnographic research about cars. We started with very simple questions: What is a car? What does it mean to own a car? To use one? To care for one? Spreading tarps next to cars, we asked drivers to unpack and explain the contents of their cars to us. We inventoried all of the items that people use, store, bring in and out, forget about, discard, rely on, transport, etc. in their cars. This exercise yielded insights on important activities, routines and social relationships that take place in/with/through/around/because of the car. These insights lead us to a further set of questions regarding automobility and inspired an expanded set of methods and theoretical perspectives from post-processual archaeology that we are deploying in the Local Experiences of Automobility (LEAM) Project.

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

General Terms
Documentation, Design, Human Factors, Theory.

Keywords
Automobility, post-processual archaeology, ethnographic research

1. INTRODUCTION

For as many cars as there on the world's roads, there is a surprisingly little social science research dedicated to making sense of them – most of the available research focuses on the ways cars function as cultural symbols and manifestations of modernity[1, 2, 3, 4, 5, 6]. We wanted to see cars with fresh eyes, and to think about them as a field site in and of themselves, as an object of study. We started with some very simple questions: What is a car? What does it mean to own a car? To use one? To care for one? Armed with a very basic set of tools: a tarp (a shower curtain, really), a folding step stool, and cameras, we set off to interview car owners and users in the US, UK, Australia, Singapore, China, Malaysia and Brazil.

As part of these interviews, we started with a bit of excavation. Spreading tarps next to cars, we drew on our archaeology training and asked drivers to unpack and explain the contents of their cars to us, while we meticulously recorded the location of each object and probed: What? Who? When? Where? Why? We inventoried all of the items that people use, store, bring in and out, forget about, discard, rely on, transport, etc. in their cars.

Such a simple exercise yielded insights on important activities, routines and social relationships that take place in/with/through/around/because of the car. It also helped us understand what car owners surround themselves with and why. The items they unpacked served as memory aids to events and routines that were difficult for us to elicit just through questions and relying on participants' unaided memories of what they had done 3 weeks prior on a Tuesday afternoon. It quickly became clear that the objects in people's cars are an important part of their car experiences. When we helped participants repack after the excavation we found that regardless of how much or how little originally came out, very little didn't go back in the car.

These insights inspired an expanded set of questions about automobility [7], and a methodology fueled by theoretical perspectives from post-processual archeology that we are exploring in the Local Experiences of Automobility Project [8].

2. (C)ARCHEOLOGY

Three observations from Car Turn Outs strongly indicate that to be successful in building solutions for smart transportation, we need to broaden our focus beyond the four wheels of the car to the specific characteristics of local automobility environments. First, talking about people's artifacts inside their cars broadens the discussion to include the large number of users and stakeholders in and around automobiles that we sometimes forget about in our concentration on the driver and her experience. Second, as more internet-connected and video playing devices make their way into cars, what belongs and doesn't belong in a car is still being worked out by drivers, lawmakers, regulators, and law enforcement. Third, what preoccupies the large number of users and stakeholders in and around automobiles is culturally and geographically specific, and cannot be addressed by car manufacturers alone.

2.1 Invisible/Visible Users
In the US, we heard repeatedly that people bought larger cars as their families grew. Chloe upgraded from a Volvo station wagon to a minivan when her two daughters both started school because "that (Volvo) could only fit a couple of kids. . . . We needed more space. . . I think once you start having kids and each of them have a friend and that's four. . . and a dog. He needs a spot too." Her car was riddled with things that don't belong to her *or* her kids: booster seats for other people's kids, toys, etc. She also had items that were not intended for anyone in the car, but for those she met while driving. For example, near her steering wheel she kept food coupons to hand out to homeless people asking for help at stop lights. Norashikin, a legal admin and mother of 4 in Penang, Malaysia, fiercely defended her new special edition Myvi SE with

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custom sound system as 'her' car – not her husband's not her children's but *hers.* She specifically bought the car for its small size – all her kids can't fit in the car at once – so her husband's car, by default, remains the family car. And yet, when she unpacked her car, we found a host of Liverpool football (soccer) decorations chosen by her eldest son (Norashikin doesn't like football); her husband's fancy commemorative pen, her sister-in-laws pregnancy log book/medical records, her son's sunglasses, an Islamic blessing to protect her bought by her husband and a slim volume of Islamic texts received as a guest gift at a wedding. These two simple examples suggest that it's not only the drivers who we should consider in designing smart transportation systems, but also other occupants, and people who interact with and are concerned about them.

2.2 What Belongs in the Car

During our interviews and excavations, car owners expressed deep ambivalence around the appropriateness of bringing and using mobile technologies in their cars, and of investing in built-in solutions to keep them more in the flow of their digital lives. There's a growing list of electronic devices such as cell phones, smart phones, tablets, portable media players and laptops that people bring into their cars, and often strata of technology on its last legs or utterly discarded in glove boxes, under seats and in door holders and on sun visors . British and U.S. car owners used their cars as a kind of purgatory for their aging CD collections, a technology no longer useful anywhere else in their lives as their music collections are fully digitized. Reggie, a design director in London quipped that "my car takes me back 10 years", yet he was unwilling to do away with his CD player in favor of an IVI system or even a stereo with USB or memory card slot; it wasn't worth investing in a technology that he couldn't take with him outside his car. For Savannah, a project manager in Portland, fixing the quirky built-in GPS system in her Toyota Forerunner wasn't worth the effort when she could just as easily find directions using her iPhone. In fact, she wasn't even sure here GPS system was broken; she blamed the faulty directions on her own shortcomings in understanding the 'Japanese logic' of the interface. You can't fix what's not broken.

2.3 Location-Specific Preoccupations

Globally, cars are considered sites of great risk. During excavations, we learned about location-specific safety concerns and local solutions to perceived dangers. These local dangers /solutions were not about the car protecting people, but rather supplementary forms of protection from potential dangers that were intimately related to being in or using the car. They are not dangers that car manufacturers could easily predict and design for globally but that smart local systems could address.

Drivers *take for granted* that their cars are constructed to help them prevent collisions and to minimize the impact. What the car manufacturers can't control is the local driving environment and the behavior of other drivers. To address this danger, almost every car we've excavated had supplemental protection against accidents in the form of religious or locally defined good luck charms: crosses, Korans, evil eye medallions, Chinese knots, Bibles, Buddha, the Virgin Mary, good luck pigs and other religious and luck pendants, statues and iconography abound on rearview mirrors and dashboards.

In Brazil, all aftermarket and portable technologies (GPS, smart phones) were brought in to the car for each drive and carried out when the car was parked. Car stereos were upgraded, but large screen, more advanced IVI systems were avoided in favor of portability. Furthermore, air conditioning and tinted windows were explicitly described as necessary safety features, rather than as a 'nice to have' features that add to the comfort of your drive in a hot climate. In Brazil, having anything built into your car leaves you a target for thieves, and leaving windows open while driving leaves you vulnerable to grab-and-dash muggings from 'Moto-boys" slipping between traffic jammed cars.

In Singapore, people were more concerned with social risks than personal and property safety. Glove compartments were filled with *ang pau*, or good luck envelopes used to gift money at New Years, weddings, birthdays and other celebrations. The possibility of showing up to an event without the proper materials to fulfill your social obligations was a much greater risk than anything that people worried about happening along the route. The explanation we heard over and over again was that *ang pau* were in cars because you never know when you might be invited to an "emergency wedding" (or show up with an insufficient gift, and need to supplement with *ang pau*). Although no one admitted this happened to them, the potential for social embarrassment was so anxiety producing that people were always prepared!

3. NEXT STEPS

What's interesting to us at Intel and what should be interesting to automobile designers is not any one of these attributes – the relationships people have with each other, their stuff or to lived experiences like safety – but to all of these in combination, in specific places like Brazil or Malaysia and while on the go. Taken together, we begin to see forming a rudimentary design space that goes beyond the car itself and considers the infrastructure and ecosystem around the car. These excavations exposed both users and practices that point to the importance of location and context both inside and beyond the car itself, and inspired our second research project, Local Experience of Automobility [8].

4. ACKNOWLEDGMENTS

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An Approach to User-Focused Development of High-Value Human-Machine Interface Concepts

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ABSTRACT
New in-vehicle technologies bring new information which must be delivered to the driver safely and efficiently. With the development of configurable display technologies, there is an opportunity to optimise the display of this information to enhance the user experience. This paper outlines the background and initial approach to a forthcoming Engineering Doctorate (EngD) research project to address the problem of information delivery from a user-focused perspective.

Keywords
User Experience, Human-Machine Interface, Simulation, Evaluation

1. INTRODUCTION
Increasing levels of technology in today's cars bring new sources and types of information, posing challenges to designers and engineers of automotive user interfaces in terms of safety, usability and affective response. For example, electric and hybrid vehicles present the driver with new information about drivetrain state, estimated range and charge state. The quality of the interaction experience will affect the users' perception of the vehicle as a whole and manufacturers must therefore seek to optimise the interaction experience.

The information sources mentioned above include those directly related to the primary task of driving the vehicle and secondary tasks such as communication and entertainment. Recent developments such as configurable dash cluster displays mean that there is more flexibility than ever before in the presentation of information to the driver.

1.1 User Experience Challenges in Automotive HMI
At the recent INTERACT '11 'User Experience in Cars' workshop in Lisbon, Portugal, September 2011, the main challenges relating to User Experience in the design and evaluation of automotive HMI were discussed. From the varied perspectives and backgrounds of the delegates, a number of reoccurring themes were identified.

The lack of consensus on a definition of User Experience (UX) was acknowledged as a key issue. While an 'official' definition is provided in ISO 9241-210:2010 ("person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service"), accompanying notes stress the extension of the scope of UX beyond instrumental measures of usability, incorporating a range of factors extrinsic to the object of the interaction, reflecting the holistic nature of the approach. While there is continuing debate as the nature of these factors [1],[2], it will be important to identify those that are critical to the perception of automotive HMI.

The application of user-derived information to the development process is of course vital to ensure that products deliver a good user experience. Indeed, users should be involved throughout the design and development process in order to ensure that the final product is aligned with customer wants and needs. However, it is important that the focus on the user does not stifle the creativity of the design team and restrict the innovation required to create a truly market-leading product.

User experience is strongly dependent on the motivations of the user at the point of interaction. It is essential therefore to replicate the context of use when collecting user data [3]. Measures of UX must consider the characteristics and goals of the user, as well as the technical and social environment of the system; hence this information must be captured and applied as part of the evaluation process.

While the previous issues discussed can be related to product development in general, the case of automotive user interfaces requires a specific focus on safety-related aspects of interaction. An interface design may provide high levels of user satisfaction in laboratory conditions but cause significant distraction from the driving task; the challenge is therefore to optimise the user experience within the constraints of what is acceptable from the perspective of safety.

Clearly, there exists an opportunity to conduct research into the effective presentation of information to vehicle users with a focus on optimising the user experience. This paper outlines the background and initial approach to a forthcoming Engineering Doctorate (EngD) research project, conducted in conjunction with Jaguar Land Rover, into a user-focused approach to the development of high-value Human-Machine Interface (HMI) concepts, describing the aims and key challenges relating to the work.

2. APPROACH
2.1 Aims and Objectives
The aim of the project is to investigate what types of information drivers need, and how HMI can be optimised to deliver a high-quality user experience. This leads to the following objectives:

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- To determine how the display of information including eco-feedback can be tailored to the requirements of the driving task, improving the user experience and reducing environmental impact
- To develop a framework for rationalising the display of information that allows designers to create effective HMI solutions
- To define design rules for the communication of information via configurable displays

In order to address these objectives it will be necessary to consider issues relating to driver distraction, workload, brand image and users' emotional responses to technology.

2.2 Methodology

The objectives require that methods for the display of information are designed and subsequently tested through a user-focused approach. The first stage of the work will be to conduct a comprehensive review of the literature, encompassing human factors, UX and Human-Computer Interaction. The main outputs from the literature review will include:

- An understanding of the key psychological factors relating to priority of information on configurable displays
- A usable definition of UX
- Identification of optimal methods for the measurement of UX in relation to in-vehicle technology

The second stage of the research will be to explore the contexts in which in-vehicle systems are used. A qualitative research approach using market research data and/or interviews with real customers will determine how information priority varies with different use cases. This, along with findings from the literature, will support the development of display concepts that are designed with a focus on user experience.

It is proposed that evaluations of information display concepts are conducted using a simulated driving environment, replicating the context of the driving scenario and real-world use cases. A medium-fidelity, fixed-based driving simulator based on Oktal SCANeR Studio software is under development at WMG and will be used to conduct evaluation trials. Further development of this capability forms part of the project.

Previous work by the authors [4],[5] established a user-centred methodology for the evaluation of in-vehicle technology which was applied to haptic feedback touchscreens. The approach comprised simulator-based evaluation conducted using a within-subjects experiment design: participants performed a series of touchscreen tasks while driving in a simple motorway scenario. Objective driver performance metrics including lane deviation, headway and speed variation were recorded by the driving simulation software; objective task performance data was also recorded using custom-developed touchscreen evaluation interfaces programmed in Adobe Flash. Subjective data on hedonic rating, user confidence, task difficulty and interference with the driving task was collected via questionnaire, using 9-point rating scales. Follow-up questions administered at the end of the study included a most/least preferred choice and Likert scale ratings of usability and user experience.

Results of these studies showed positive indications for the validity of the methodology, with the successful generation of rich information which offered insights into users' perceptions of technology, above and beyond instrumental measures of usability [6]. However, it is acknowledged that the methodology does not provide a comprehensive picture of UX; this must therefore be addressed through the incorporation of methods identified in the literature review prior to application to this research problem.

In the final stage of the research, the outputs from the evaluation studies will be used to develop the design rules and framework described in the objectives. In considering the context of evaluation and acquiring data on safety-relevant objective performance metrics alongside subjective measures of user response, the challenges to UX in automotive HMI discussed in section 1.1 are addressed.

2.3 Challenges

As discussed above, there is ongoing debate regarding the definition of User Experience and how to define the context of evaluation. Given the holistic nature of the problem, a challenge exists in ensuring that the key factors that shape UX are considered and that the correct data gathering methods are employed. Further work will be required to ensure that the scope of the evaluation is developed to allow this.

The main challenge to the success of the project however is one of validation. While simulated environments provide an enhanced context of evaluation, it can be difficult to determine the extent to which real-world behaviour is replicated. It will be important to correlate simulator findings with road-based data and/or results from an alternative simulator with established validity.

3. SUMMARY

New in-car technologies bring new sources and types of information, the delivery of which must be carefully managed to optimise safety and user experience. The approach described within this paper proposes using driving simulator-based evaluations to generate rich, context-relevant information on users' response to HMI concepts, with the aim of delivering a framework for rationalising the display of information within the vehicle. Challenges to the research include establishing the key elements driving user experience and determining the validity of the evaluation environment.

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Part II.

Interactive Demos

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The ROADSAFE Toolkit: Rapid Prototyping for Road-Testing Novel Automotive User Interfaces

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ABSTRACT

The design and evaluation of efficient feature-rich, yet non-distracting automotive user interfaces for driver assistance is an increasingly challenging task. To reduce efforts as well as to complement and validate lab studies under real-world conditions, we developed the latest version of our ROADSAFE toolkit, a highly flexible framework for prototyping and evaluating novel automotive user interfaces on the road. The toolkit is especially targeted at HCI researchers with a focus on easy creation and adaption of interfaces considering short design iterations and off-the-shelf hardware. Further, the ROADSAFE toolkit offers a series of features which enable the investigation of user aspects of current and future in-car applications including real-time multimedia supplements on different quality levels, interactive scenarios requiring user input and deployment on arbitrary end devices.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Prototyping, Evaluation/methodology*

General Terms

Design, Human Factors

Keywords

User interface, widgets, multimedia, interactive, road test

1. INTRODUCTION

Due to the rapidly growing complexity of both a car's functionality and accessible contextual information, the design of efficient in-car Human Machine Interfaces (HMIs) is one of the key challenges in Automotive Software Engineering [1]. Thereby, advanced driver assistance is an especially important trend [5]. With technological advances such as Vehicle-to-Infrastructure (V2I) environments collecting and exchanging relevant traffic data in real-time, vast amounts of new information is and will be available. However, corresponding warnings and instructions need to be communicated to the driver in a safe manner, informing about relevant details in an efficient, non-distracting way. We argue that HCI researchers need a rapid prototyping toolkit in order to test novel interfaces under real-world conditions on the road to complement respective in-car HMI lab studies. A suitable toolkit must be highly flexible and extensible, allow for short design iterations without writing code and offer built-in support for validating future in-car use cases involving multimedia applications and interactive elements.

One related approach focussing on a flexible UI model for in-car HMIs is proposed by de Melo et al. [2]. The authors suggest the creation of suitable automotive UIs from abstract representations for integrating external applications. Another approach is *FLUID* (Flexible User Interface Development) [6] developed by *BMW Car IT* offering a layered architecture and modular UI components. However, *FLUID* is executed on the vehicle's embedded processor and therefore its application is limited to automobile manufacturers. Also targeted at the automotive industry is *Windows Embedded Automotive* with its *Automotive UI toolkit* [3] featuring sophisticated design tools but offering no special support for the conduct of road-tests and the evaluation of future in-car use cases.

The ROADSAFE toolkit presented in this paper is detached from the car's electronics and runs on a modern laptop computer operated by a test manager on the back seat. Extending an earlier version [4], our present toolkit not only allows for rapid UI design adaptations but has been substantially updated, e.g., it now allows for the easy device-independent creation of multimedia and interactive test scenarios.

2. THE ROADSAFE TOOLKIT

The presented toolkit is implemented in *Python* enabling the easy extension in future utilizing concepts of a modern dynamic programming language. The latest version of the ROADSAFE toolkit offers the following features:

Reusable widgets. In our prototyping toolkit, user interface elements are encapsulated as *widgets* which define the element's appearance and behavior. Each widget is a separate Python class derived from a widget super class. In addition to general attributes, such as position and size, each widget has access to one central *data repository* object, where current values of relevant contextual variables can be retrieved. For example, a traditional bird's eye map widget (shown in Figure 1) makes use of the current location of the car and a info widget accesses the list of currently relevant safety messages.

Flexible UI configuration. The overall layout of the UI is defined by *skins* which place widgets at certain screen locations

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Figure 1: Real-time safety message with a live preview image.

Figure 2: Interactive "Park and Ride" scenario with an AR view.

Figure 3: Traffic camera view with a smartphone as end device.

and set some of their visual and behavioral properties. For each test person, we prepare a *scenario* which defines different sections of the respective test drive and specifies which skin to use for each section. The skins may be changed at defined trigger locations or manually by the test manager during the test drive, e.g., to switch between a traditional bird's eye view and an Augmented Reality (AR) view (depicted in Figure 2). Both skins and scenarios are defined in easily interchangeable XML files. Hence, the toolkit allows for the quick and easy adaption of visual apperance and behavior.

Multimedia integration. In addition to a high-quality text-to-speech engine for auditive feedback, our toolkit allows for the integration of custom multimedia content. This allows us to investigate end user requirements for future V2I multimedia services which may include live videos from traffic cameras. Again easily definable in XML, we are able to prepare distinct configurations for test drivers and confront them with different quality settings from still images up to high-quality videos for exploring the required quality levels from a user perspective (see Figures 1 and 3).

Interactive scenarios. Besides driver assistance in form of traditional turn-by-turn navigation and real-time safety messages, new interactive in-car use cases are emerging. One example is the consideration of alternative transport possibilities and the recommendation of multimodal routes in real-time (Figure 2). The ROADSAFE toolkit supports the investigation of such scenarios: again, without programming know-how, interactive elements such as buttons can be integrated and defined in skins using XML. Triggered actions include the change to another skin (e.g., to switch between different views) and playing of sounds and speech messages (e.g., to provide an auditive route description).

Arbitrary end devices. Competing with dedicated navigation devices, feature-packed smartphones and even tablets are increasingly used for driver assistance. Since optimal communication strategies for driver information may vary for different target devices (primarly due to different display sizes), a prototyping toolkit must support arbitrary end devices. In addition to the obvious solution of attaching an external display for the driver via a video connector, the ROADSAFE toolkit integrates a custom video streaming module. Thus, we are able to provide a smartphone or tablet PC with visualizations by the same rendering engine, conveying the impression of a fully functional smartphone application for the test driver (Figure 3). Of course, interactive scenarios are also supported in this setup: touches on the end device are forwarded to the laptop computer where respective mouse actions are triggered.

Demo mode. The creation and validation of road-test scenarios can be expensive in terms of both time and money. To reduce efforts, our toolkit offers a demo mode for reviewing the defined route and occuring events: GPS traces (e.g., recorded by a GPS mouse or created by a route planner) can be easily integrated in our toolkit to simulate test drives apriori in the lab and prepare testing scenarios, e.g., to finetune trigger locations of messages for the road test.

The ROADSAFE toolkit and its concepts proved to be highly useful for several user studies investigating in-car HMI research questions under real-world conditions.

3. ACKNOWLEDGMENTS

This work has been carried out within the project ROADSAFE financed in parts by the Austrian Government and by the City of Vienna within the competence center program COMET. The authors additionally would like to thank *ASFINAG* and *Fluidtime* for providing some of the basic software modules for the presented prototyping toolkit.

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SpeeT: A Multimodal Interaction Style Combining Speech and Touch Interaction in Automotive Environments

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ABSTRACT
SpeeT is an interactive system implementing an approach for combining touch gestures with speech in automotive environments, exploiting the specific advantages of each modality. The main component of the implemented prototype is a speech-enabled, multi-touch steering wheel. A microphone recognizes speech commands while a wheel-integrated tablet allows touch gestures to be recognized. Using this steering wheel, the driver can control objects of the simulated car environment (e.g., windows, cruise control). The idea is to use the benefits of both interaction styles and to overcome the problems of each single interaction style. While touch input is well suited for controlling functions, speech is powerful to select specific objects from a large pool of items. The combination simplifies the problem of remembering possible speech commands by two means: (1) speech is used to specify objects or functionalities and (2) in smart environments - particularly in cars - interaction objects are visible to the user and do not need to be remembered. Our approach is specifically designed to support important rules in UI design, namely: provide feedback, support easy reversal of action, reduce memory load, and make opportunities for action visible.

Categories and Subject Descriptors
H5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces – Interaction Styles (e.g., commands, menus, forms, direct manipulation).

General Terms
Human Factors.

Keywords
Gesture, speech, multimodal interaction, automotive user interfaces, smart environments.

1. INTRODUCTION
Multimodal technologies offer a great potential to reduce shortcomings of single modalities for interaction. Although quite some research on multimodality has been conducted and some general guidelines have been shaped (e.g., [3]), no specific patterns or interaction styles for an appropriate integration of different modalities have emerged yet. SpeeT (Speech+Touch) is implemented to evaluate the concept of combining speech and touch gesture input for interaction with real objects. The concept was designed based on design rules and usability heuristics, centered around a formative study to gather user-elicited speech and gesture commands.

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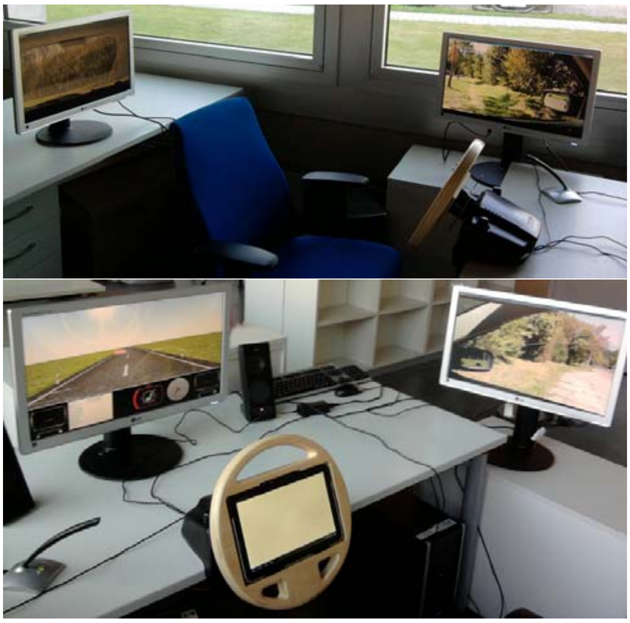

Figure 1: Prototypical implementation of our multimodal interaction style – a microphone captures speech commands while gestures are performed on a multi-touch steering wheel. Screens around the driver's seat simulate the back window, driver/passenger windows and the exterior mirrors. The front screen displays the driving simulator and a virtual dashboard.

Speech input is very powerful in selecting functions and objects by naming them without a need for hierarchical structures and explicit navigation. Gestures instead support fine-grained control of functions very well and permit easy reversal of action. For the automotive domain, previous research has shown that gestures are powerful as they require minimal attention and can be performed without taking the eyes off the road [1], whereas interaction with (graphical) menus and lists is visually much more demanding and results in more driver distraction. Further results are that finding intuitive gesture commands to select functions can be difficult [1]. Based on these insights, we developed a multimodal interaction style where the object to be interacted with and the function that is performed are selected by voice and the actual control is done by a gesture. We expect that the presented interaction style will reduce the visual demand during interaction. In this paper, we report on the design of a first prototypical implementation.

2. USER EXPERIENCE & INTERACTION
Sitting behind a multi-touch steering wheel, the user can manipulate several objects/functions in the (simulated) car by using the proposed multimodal interaction style that combines speech and

gesture interaction (see Figure 2): First, *speech* is used to *select* and *quantify* one or multiple *objects* and their *function* to be controlled. If an object offers only one function to be modified, the selection process can be shortened by just calling the object and implicitly choosing its function, e.g., “cruise control”. If multiple instances of an object type exist (e.g., windows), the desired objects need to be quantified (e.g., “passenger window”). The interaction can also be started by just saying the object’s name (“window”) – if the selection is ambiguous, the system will ask for a suitable quantification until the object and function selections are well-defined. Similarly, for objects offering more than one function, the user clearly has to select the desired function. An integrated disambiguation cycle (see Figure 2) assures an explicit selection of object(s) and function by providing speech prompts to refine the selection if necessary. As the objects are visible in the corresponding environment, it is easy to remember the items of the interaction space and to comply with the visibility principle. Thus, even a larger number of items can be addressed without an increased memory load. After the selection of the interaction object(s) and function, a modality switch takes place and the user performs gestures to modify the desired parameters. This allows for a fine-grained control and an easy reversal of actions. As the action is executed immediately, a direct feedback is given by means of manipulated objects.

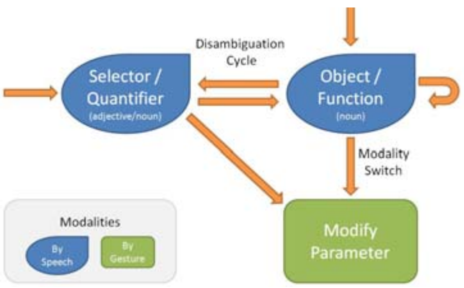

Figure 2: Diagram of the speech-gesture interaction style – Interaction objects are selected by speech and then manipulated by (touch) gestures.

3. STUDY AND IMPLEMENTATION

In a first study conducted with 12 people (2 female, 20–39 years, avg. age 28,25 years; avg. driving experience 10 years) we validated the hypotheses that users can easily identify objects and (secondary and tertiary [2]) functions in the car by speech input without prior training and that users have similar expectations with regard to gestural control. At the same time, the study was used to gather user-elicited speech and gesture commands. In this study, the users first had to identify objects/functions of the car that were presented as pictures on our touch-enabled steering wheel. As a second step, the users should propose a touch gesture to control the corresponding parameter. In 97.8% of the presented scenarios people were able to easily find appropriate terms to name visible and known objects (82.1%) and/or their functions (15.7 %). The study showed, that it is crucial to realize a broad set of different voice commands for a single functionality and that the denotations of visible objects have potential for intuitive voice commands. Further, the study revealed a high agreement on touch gesture commands among participants. Overall, they did not have problems to think of touch gestures and chose very similar and simple gestures to control different functions. 86.5% of the recorded gestures were simple and easily transferrable directional gestures (up/down/left/right). These gestures are based on embodied conceptual metaphors and seem well suited to control the parameters of most objects’ functions.

The setup for the study included a speech-enabled multi-touch steering wheel, which was connected to a driving simulator (CARS[1] open source driving simulation) that ran on a PC with a 24” screen. As a steering wheel, we used a commercial Logitech G27 racing wheel base and replaced the actual wheel by a self-made wooden steering wheel containing an integrated Android-based tablet (see Figure 1). An Android application was designed for the study to gather verbal commands and gestural input by presenting different objects and functions in the car.

Encouraged by the results of the study, SpeeT was constructed as an iteration of the prototype. While keeping the steering wheel and driving simulator, a virtual dashboard is included on the front screen (driving simulator) showing gauges for air vents, the current speed (cruise control) and the seat heating. Screens on the left and right side show the driver and passenger windows and the exterior mirrors. A fourth screen simulates the rear window and wiper. By using the proposed interaction style all aforementioned objects can be controlled. A USB microphone captures voice input while gestural input is gathered by an Android app on the tablet and broadcasted via UDP to a control application on the PC. There, all events are processed and mapped to the available functions. This allows the driver to use voice commands to select objects / functions and to conduct gestures to modify the related parameter. Speech interaction is initiated either by using a button on the back of the steering wheel or saying the word “command” to fully activate the speech recognition system. If a speech command is ambiguous, speech prompts (disambiguation cycle) ask to refine the object selection. Direct visual feedback is given to the user by providing the corresponding simulation like an opening window. Figure 1 illustrates the prototypical implementation.

4. CONCLUSION

In this paper, we present a first prototype implementing our novel interaction style to combine speech and (multi-) touch gestures for multimodal input. Speech is used to select the function based on visible objects in the environment. Touch is used to control parameters, providing immediate feedback and easy reversal of action. With this interaction style the advantages of both modalities are exploited and the drawbacks are reduced. A first study revealed that this interaction style is understandable to users. As a next step, we will investigate how visual demands change by using this interaction style compared to existing interaction styles.

5. ACKNOWLEDGMENTS

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Dialogs Are Dead, Long Live Dialogs: Building a Multimodal Automotive Application for Both Novices and Experts

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Abstract: *We describe a prototype car navigation system with a high level of sensitivity towards the differing abilities of users and the differing levels of visual and cognitive demand in real-world driving. The system, called VoiceCar, supports conventional, step-by-step, mixed-initiative voice dialogs and commands as well as more open-ended, entirely user-initiative interactions (which we term "anti-dialogs"). Much validation work remains to be done, but we hope that our demonstration system's support for both dialogs and anti-dialogs makes it more adaptable to a variety of driving situations, to users of all levels, and to illdefined or shifting user intentions.*

This work was originally submitted as paper with an accompanying demo to the "Industrial showcase" category; to avoid duplicity the full paper is published in the "Industrial showcase" adjunct proceedings only.

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Part III.

Posters PDF’s

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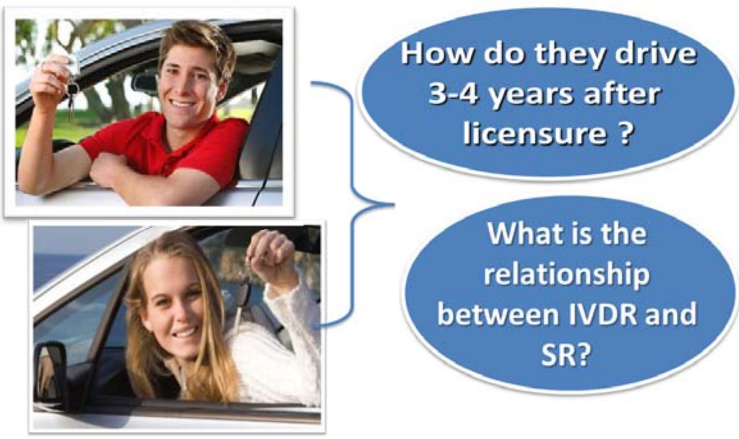
THE USE OF IN VEHICLE DATA RECORDERS AND SELF-REPORTED DATA FOR EVALUATING DRIVING BEHAVIOR OF YOUNG DRIVERS

Gila Albert, H.I.T – Holon Institute of Technology, Israel

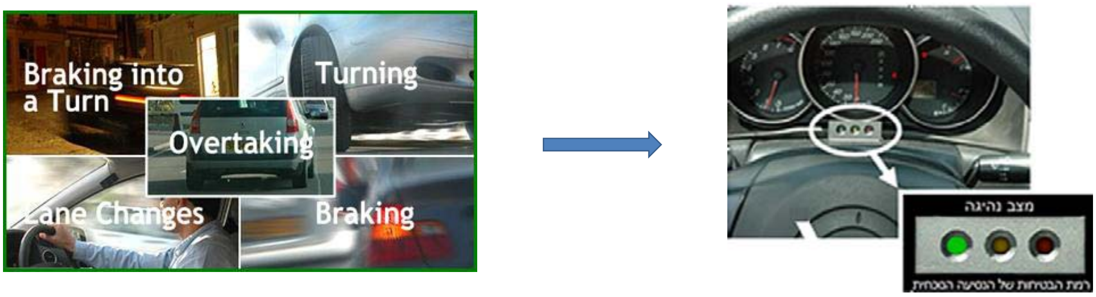
Tsippy Lotan, Einat Grimberg, Or Yarok, Israel

Tomer Toledo, Technion, Israel, Mariano Lasebnik, H.I.T, Israel

ABSTRACT This paper aims to evaluate the driving behaviour of young drivers few years after licensure. The evaluation is based on two kinds of data: In Vehicle Data Recorders (IVDR) and Self-Reports (SR). The results show that young drivers clearly perceived themselves as safer drivers than they are according to IVDR. The results also suggest, based on the two approaches, that young driver improved their driving behavior while driving with IVDR. The analysis obtained should be considered as exemplifying the potential of what may be done with these two evaluation approaches.

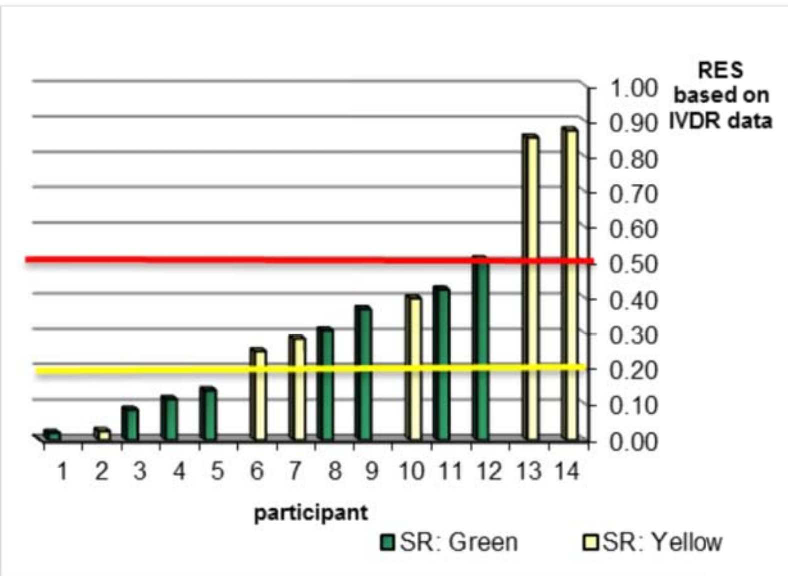


METHODOLOGY IVDR systems have been installed in the private cars of the participants, 32 young drivers with 3-4 years of driving experience at average age at the time the study started of 20.5 ± 0.5 years. participants were asked to fill in specific trip diaries regarding various characteristics of the trips they had. Study period: 8 months.



RESULTS The comparison of IVDR data and SR data was done with respect to two factors: driving exposure and trip safety evaluation.

- High correlation (>0.9) of driving exposure which was self-reported and data obtained from IVDR.
- The young driver improved their driving behavior while driving with IVDR and they are aware of this improvement.
- The young drivers self-reported the trips they undertook as significantly safer, compared to the IVDR evaluation. They perceived themselves all the time as less risky drivers than they are.



DAIMLER

Information Extraction from the World Wide Web Using a Speech Interface

Hansjörg Hofmann (Daimler AG), Ute Ehrlich (Daimler AG), Andreas Eberhardt (BitTwister GmbH)

Abstract

- Accessing the World Wide Web while driving puts the driver's safety at risk

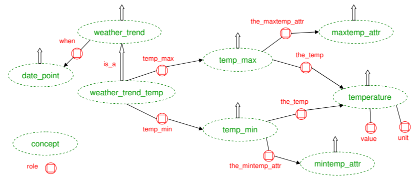
➔ Need for an intuitive speech interface to the Web based on:

a) Information Extraction (IE) algorithm
   - extracts topic related information from the Web which is available in *unknown* web page structures

b) Generic speech dialogue
   - Designed in an intuitive and driver-convenient way in order to not distract the user

Information Extraction From Semi-Structured Web Sites

- Previous approaches to IE focus on the web page's HTML DOM tree to extract relevant information
- Here: definition of an ontology (defined in KL-ONE) to a certain topic
  - ➔ use web sites as our source to find matching information
- Example ontology for the topic "weather":



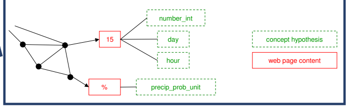
1.) HTML Parser

- Analyzes the web site and generates a preliminary internal representation:
  - Dynamic contents (e.g. AJAX scripts) are processed
  - Embedded frames are loaded
  - Referenced web sites are taken into consideration

➔ Internal representation as a cyclic graph

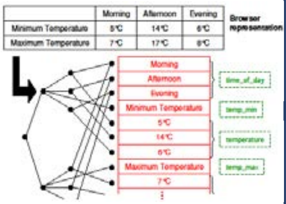
2.) Text Parser

- Analyzes the textual content
- By applying topic oriented grammar definitions initial concept hypotheses of the semantic model are generated



3.) Graph Transformation

- Transformation into a simple and standardised internal representation to accelerate the matching process
- Structural, context sensitive and HTML-tag specific rules are applied

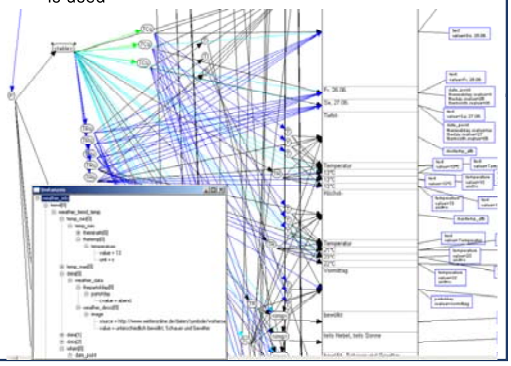


4.) Matching Algorithm

- Maps the graph structure onto the concepts of the predefined semantic model
- Different evaluation criteria are applied
  - E.g.: Only one subset of hypotheses allows the instantiation of a hierarchically higher concept
- Knowledge from parser grammar and semantic model is used

- Result of the matching algorithm:
  - Set of instances containing the most probable concept instance hypotheses
- Result is available in the structure of the semantic model

➔ Can be presented by the speech dialogue



System Prototype

- For the topic "weather" a prototype has been implemented:
  - Ontology was created, the text parser grammar and the speech dialogue was designed

Generic Speech Dialogue

- Dialogue is modelled as a hierarchy of sub-tasks including roles
- According to the user's input a system reaction is triggered
  - ➔ dialogue becomes very flexible and adapts to the user's input
- Generic speech dialogue is adapted to the ontology and modelled for each topic explicitly
- By keyphrase spotting the user's input is understood and mapped onto the ontology

Evaluation of the IE Algorithm

- Standardised weather definiton:
  - Forecast for 3 days: Today, tomorrow, the day after tomorrow
  - Four weather descriptions ("sunny", "cloudy", "rainy", etc.) per day: Morning, afternoon, evening, night
  - Two temperature values per day: Maximum and minimum value
  - Precipitation information per day: Probability and amount
  - Wind details per day: Direction and strength

Web Site	Available data w.r.t the standard weather definition	Extracted data w.r.t. available data
www.wetter.com	100%	91%
www.wetter.de	67%	53%
www.wetteronline.de	81%	100%
www.wetter.net	86%	0%
www.donnerwetter.de	65%	72%

AutomotiveUI'11, Nov 29 – Dec 2, 2011, Salzburg, Austria. Please see the paper for more information and references.

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Multimodal Display Integration for In-Vehicle Assistive Technology (IVAT)

Julia DeBlasio Olsheski & Bruce N. Walker

ABSTRACT

Individuals who have survived a traumatic brain injury (TBI) can experience a variety of sequelae that may limit their ability to drive. Assistive technology can be leveraged in the context of driving to facilitate autonomy for this population. Multisensory integration is known to have facilitatory capabilities at the neural, cognitive, and behavioral levels. The extent to which these enhancements could aid those with TBI is not well understood. We have the opportunity to address the needs of this user group by utilizing multimodal interfaces. The aim of our in-vehicle assistive technology (IVAT) project is to increase driver safety by first considering individual abilities and limitations and then tailoring support to meet those specific needs.

Georgia Tech School of Psychology Driving Simulator Facility

DRIVING AFTER TBI

- Driving after TBI has been identified as a critical component of reintegration into the mainstream community.
- Cognitive, behavioral, and physical sequelae commonly associated with TBI have been shown to have negative effects on safe driving.

MULTIMODAL PERFORMANCE FACILITATION

- Facilitatory performance effects include:
  - faster reaction time
  - increased accuracy
  - decreased detection thresholds
- Level of multimodal neural enhancement increases with:
  1) the degree of spatial overlap due to stimuli falling within increasingly aligned receptive field excitatory regions
  2) the degree of perceived synchrony of multimodal inputs due to maximal overlap in respective periods of peak neural activity
- Outside spatial and temporal multisensory integration boundaries lie an inhibitory region where perceptual processes act to suppress neural response

FUTURE RESEARCH GOALS

- Driving Performance
  - Braking Reaction Time
  - Following Distance
  - Lane Deviation
- Situational Awareness
  - SAGAT Technique
- Subjective Workload
  - NASA TLX

- Provide empirical evidence to corroborate anecdotal findings from initial needs assessment group that system does correlate with better driving performance.
- Define the temporal and spatial boundaries necessary for audiovisual performance facilitation for this user population.

ENGIN (Exploring Next Generation IN-vehicle INterfaces): Drawing a New Conceptual Framework through Iterative Participatory Processes

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ABSTRACT

This poster presents an initial stage of the ENGIN (Exploring Next Generation IN-vehicle INterfaces) project. In order to create next generation in-vehicle user interfaces, iterative participatory processes were used: brainstorming, drawing affinity diagrams, conducting focus groups, and hosting expert panel sessions. Through these various inputs, we tried to balance among technology trends and feasibility, users' needs, and experts' considerations. This explorative study approach is expected to provide a blueprint of the automotive user interfaces in the near future and to guide researchers in academia and industry.

Categories and Subject Descriptors
H.5.2. **[Information Interfaces and Presentation (e.g., HCI)]**: User Interfaces – interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design

General Terms
Design, Human Factors

Keywords
Next Generation In-vehicle Interfaces, Participatory Design

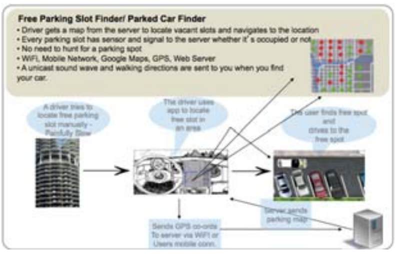
CONCEPT-DRAWING PROCEDURE

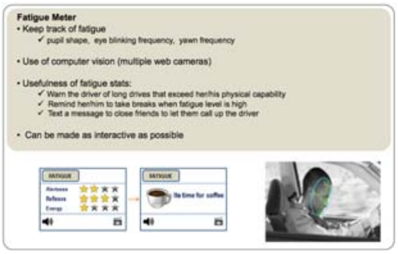
✧ Brainstorming & Affinity Diagram Sessions

✧ Focus Group Sessions

✧ Expert Panel Sessions

Figure 1. Concept-drawing processes included (a) Brainstorming, (b) Affinity Diagram (c) Focus Groups, and (d) H/F Expert Sessions.





GT Sonification Lab

Georgia Institute of Technology

The HMISL language for modeling HMI product lines

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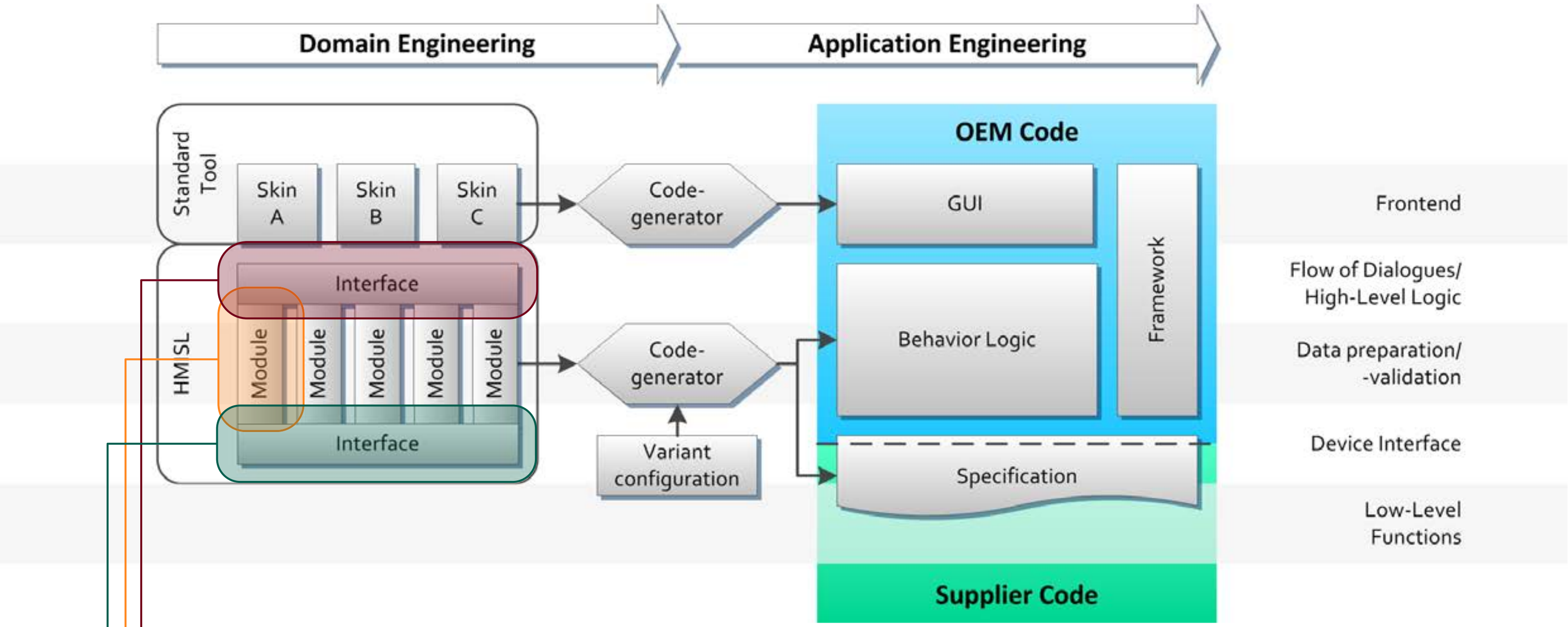
- Domain specific language for model-driven development of Automotive HMI Software
- Designed for being combined with different GUI modeling tools available on the market
- Allows to model behavior logic modules reusable for creating different product variants
- Code of product variant is generated based on module selection and parameterization




```
interface gui myGui {
      animation fadeSeekToManulMode;
      ...
      scene seekScreen {
            interaction manualTuning;
            property string stationName;
            ...
      }
      scene manualTuningScreen {
            property integer tunedFrequency;
            ...
      }
      popup temperatureWarning priority 10 {
            ...
      }
}
```

- GUI design is created externally
- GUI interface defines “remote-controlled” elements in GUI and interaction events
- GUI interface independent of actual GUI layout

```
module radio uses myGui {
      public event manualTuning;
      public variant integer defaultFrequency;
      ...
      statemachine main start seekMode {
            state seekMode {
                  on enter show seekScreen;
                  on manualTuning {
                        if (defaultFrequency != -1)
                              set tunedFrequency to defaultFrequency;
                        goto manualMode;
                  }
                  ...
            }
            state manualMode {
                  on enter show manualTuningScreen;
                  ...
            }
      }
}
```

- Description of HMI behavior
- Reactive programming paradigm: combines scripting language and high-level constructs (e.g. events, state machines, data binding…)
- Elements of GUI interface are accessible
- Placeholders for variant specific values

Depending on Supplier/OEM

- Maps supplier/OEM specific interface technology to generic concepts like events and variables
- Specification of base function and call sequences

Poster PDF missing...

Christian Doppler Labor
Contextual Interfaces

Mind the Context

An in-situ study to investigate the usage of In-Vehicle Information Systems

Focus
Investigation of the usage of multifunctional In-Vehicle Information Systems (IVIS) such as BMW iDrive or Audi MMI

Background
Application of an in-situ study (contextual inquiry)
What is the advantage?
=> gain information about the user's actual experience
=> attain a deeper understanding of user's actions

Study Setup
- 10 participants, regularly using an In-Vehicle Information System (IVIS) e.g. BMW iDrive, Audi MMI
- Average Age: 36,9 years (9 male, 1 female)
- One observer, sitting in the front passenger seat

Figure 1: Influencing Context Factors

Central Research Goals
- Investigate how participants use the central rotary knob in order to carry out tertiary tasks (RG1)
- Explore to what extent interactions with the system have an influence on the primary task of driving (RG2)
- Identify users' experiences and requirements towards the system (RG3)

Results (selected)
Performed tasks (RG1):
- Importance of additional information the navigation system provides (e.g. arrival time, distance to final destination, etc.)
- Voice command is hardly used to operate the telephone - participants preferred to operate the teleophone via the central controller

Influence on the primary task of driving (RG2):
- Suddenly changing contextual conditions (e.g. traffic light turns read) had a striking influence on the primary task of driving when simultaneously operating the IVIS (e.g. driver could just stop before the traffic light in time)
- The operation of the navigation system during the ride caused more distraction than the driver was conscious of (e.g. driver took the wrong way)

User Experience and Requirements (RG3):
- Possibilities to enhance safety while driving are rarely used (e.g. voice command to operate the telephone)
- Mismatch between perceived and actual safety

Conclusion
- The CI was identified as a valuable approach to investigate the driver's behavior in the car
- As an improvement an additional observer and/or a video camera could be added

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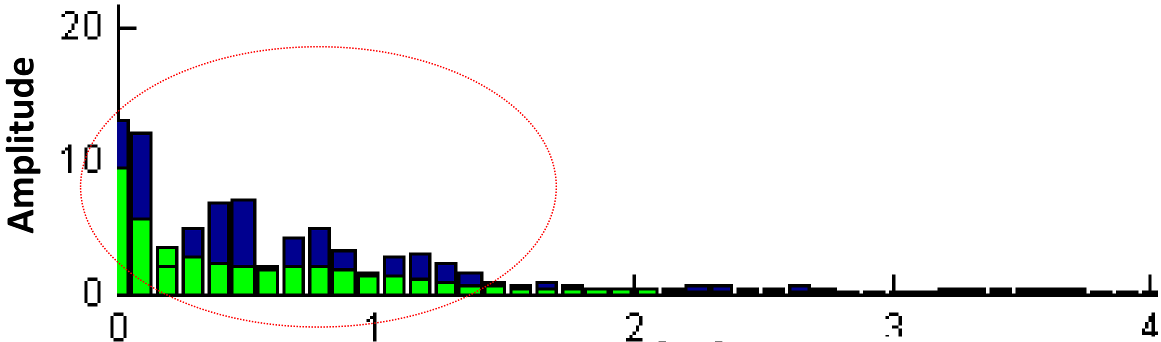
AUDIO MOBIL
infineon

Tobias Islinger, Thorsten Koehler, Bernd Ludwig
Automotive UI 2011, Salzburg

Driver distraction analysis based on FFT of steering wheel angle

Driver Distraction causes a lot of (deadly) accidents every year

Therefore, we focus on the steering wheel angle to detect and avoid distracted driving situations



By making a Fast Fourier Transformation of the steering wheel angle, we can see differences in the spectra between normal (green) and distracted (blue) driving

- Average amplitude range from 1 to 7
- Less steering corrections

- Averge amplitude range from 3 to 12
- Max value of amplitude much higher
- Big problems with lane tracking

Christian Doppler Labor
Contextual Interfaces

Gas Station Creative Probing: The Front Seat Passenger

The recruitment process for a creative probing study that aimed to get inspirations for innovative and creative user interfaces for front seat passengers is a challenging endeavour:

- The target group is hard to reach and changing (not bound to a single car or driver)
- Participants often misunderstand the requirements to take part in a study (own a car)

Gas Station Recruiting

We propose the gas station area (Fig. 1) as a recruiting platform, as front seat passenger can be met in the respective context and have time to participate. We regard the following aspects as essential:

- The gas station surroundings (e.g traffic, location)
- Study target group (e.g. transients, passengers)
- Study process (e.g. willingness, timing)

Study Example: Creative Probing

An inital study showed the potential of the recruitment process and further benefits:

- Participants conduct in-situ exercises (Fig. 2)
- The context car serves as inspiration and is usab le as an idea showcase (Fig. 3)
- 80 exercises, 30 booklets, 100 pictures collected

Regarding the effort and the quality of the collected data the approach proves his applicability.

Figures 1-3 (in decending order):
1) Gas station creative probing context
2) Participant conducting an exercise in the car context
3) Demonstrating the best position for a front seat passenger in-vehicle information system

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German Research Center for Artificial Intelligence GmbH

A New Icon Selection Test for the Automotive Domain Based on Relevant ISO Usability Criteria

Verena Johann, Angela Mahr

1. Introduction

- User-friendly designed icons can influence a human machine interface positively in several ways [1]
  - can be found and recognized quicker
  - better memorable
  - not bound to a specific language
- Icon use can also be seen critically [2]
  If the meaning of the respective icons is not obvious and captured entirely → increasing error rate could result
- ISO 9241-110 [3] applied to in-vehicle driver information or assistance systems results in the following relevant criteria: ***Manifestness, task adequacy, self-descriptiveness, conformity to expectations, learning supportiveness.***
- We developed a new method to test predesigned icons

2. Icon Set

- 54 icons overall (18 diverse functionalities x three icons each)
- Warning or information content

Examples

Warning icon
„Attention, heavy rain!“

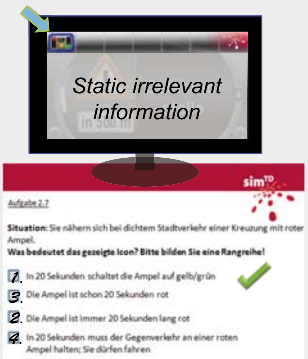
Information icon
„Remaining red light time“

1. 2. 3.

3. Icon Test

24 Subjects (12 female & 12 male; age: 20 – 57 years; paid 8 €)

Task 1



- ***Tested criteria***: Manifestness, understandability, self-descriptiveness, task adequacy
- ***Setup:*** Icons presented on a 7'' display & evaluation booklet
- ***Task:*** Assessing the meaning by ranking four possible descriptions
- ***Evaluation:*** Correct meaning: 1st place → 3 points, 2nd place → 2 points, ...

Task 2

+ 14 other feature screens

- ***Tested criteria***: Conformity to expectations, task adequacy
- ***Setup:*** Printouts of all 54 icons and of the 18 larger feature information screens (more detailed illustration) it represents
- ***Task:*** Assign each icon to the matching information screen
- ***Evaluation:*** Correctly assigned icons → 1 point **(points x 3)**

Task 3

- ***Tested criteria***: Manifestness, task adequacy, self-descriptiveness
- ***Setup:*** Task booklet with feature description and larger feature screen
- ***Task:*** Priority rating for the three alternative icons
- ***Evaluation:*** Best icon → 2 points **(points x 1.5)**

Task 4

3 days later

- ***Tested criteria***: Learning supportiveness, manifestness
- ***Setup:*** List with all 54 intermixed icons via email
- ***Task:*** Free recall and description of the meaning
- ***Evaluation:*** Answers rated with four-level rating scale (0-3 points)

4. Results

- Scores from all 4 tasks were added up. For each of the 18 features: At least one usable icon (score > 8) was found and information whether improvement might be worthwhile (score < 10).
- Examples: Warning icon 2 was significantly better than icon number 1 ($p < .05$) and icon 3 ($p < .001$). Information icon 2 earned a significantly higher score than icon 1 ($p < .001$) and icon 3 ($p < .001$).
- Warning icons were rated significantly higher than information icons (mean = 9.6 vs. 9.0; $t(46) = 5.2$, $p < .001$).

Exemplary results one warning and for one information feature

Feature	'Attention, heavy rain!'			'Remaining red light time'		
Icon	**1.**	**2.**	**3.**	**1.**	**2.**	**3.**
Task 1	2.4	2.7	2.8	2.2	2.8	2.2
Task 2 (x3)	1	1	1	1	0.9	1
Task 3 (x1.5)	0.5	1.9	0.5	1.1	1.4	0.4
Task 4	2.5	2.9	2.9	2.6	2.9	2.8
Total	8.9	11.5	9.5	9.6	10.8	8.7

5. Conclusion

- This test can differentiate between diverse forms of illustration and fundamentally support the icon selection process.
- It is an extensive method to review icons and especially fits the automotive domain.

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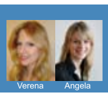

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The Process of Creating an IVAT Plug-in: Mirror Checking

Thomas M. Gable, Richard Swette, Alan M. Tipert, Bruce N. Walker and Sundararajan Sarangan

Sonification Lab, Georgia Institute of Technology

Introduction

- 5.3 million Americans have had a traumatic brain injury (TBI) [1]
- Each year 1.5 million new brain injuries [1]
- TBIs can result in cognitive impairment [2]
- Driving is challenging for TBI clients
- Independent driving is important for becoming independent post-injury [2]
- Drivers with TBIs often report problems with safe driving practices [3]

IVAT Background

- Shepherd Center and the Sonification Laboratory collaboration
- Developing an In-Vehicle Assistive Technology (IVAT) system

- Shepherd Center rehab experts built hardware electronic driving coach (EDC) [4]
- EDC had three hardware buttons, each corresponding to a routine driving task
- Driver pressed a button after performing a task, received positive feedback
- EDC use led to improved driving habits

- Sonficiation Lab extended and expanded the EDC into software system, IVAT [5]

- In-Vehicle Assistive Technology (IVAT) is a system of software apps ("plug-ins")
- Plug-ins run alone or together to create a personalized and adaptive system
- Plug-ins designed for driving tasks identified through interviews and focus groups with driving rehabilitators as affected by TBI

Choosing Mirror Checking and Primary Considerations

- Maintaining spatial and situational awareness (SA) is a vital part of safe driving [6]
- TBI drivers' frequently have problems with SA [7]
- Checking mirrors selected as the function of the first purpose-built IVAT plug-in
- Employed Interviews, focus groups, and iterative evaluations of prototypes with potential users and driving rehabilitators [5]
- Must avoid adding to driver's cognitive load!
- Plug-in must keep ore be able to regain driver's attention [5]

Planning the System

IVAT configuration in the GT School of Psychology's National Advanced Driving Simulator MiniSim

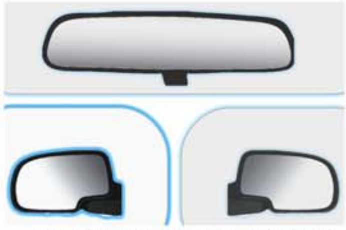
- System functions:

1. Issue task reminder
   a) determine when to issue reminder
   b) issue the reminder
2. Register task completion
   a) recognize completion
   b) communicate recognition

GT Sonification Lab

Making Design Decisions

- Multimodal cues maximize notification effectiveness
- Minimize additional cognitive load [8]
- System flexible, use multiple inputs:
  - A touch screen
  - Buttons on steering wheel
  - Eye-tracking device
    - Supports automatic recognition of mirror-checking behavior



Touch screen display after issuing the first third of the notification

Primary System

- Output for Version 1.0 was audiovisual.
- Three mirror icons illuminated sequentially, in time with three sequential tones
- Auditory notification was major chord, played spatially:
  - Driver side mirror: root note of chord (e.g., C) from front-left speaker
  - Rear view mirror: musical fifth (e.g., G) from both front speakers
  - Passenger side mirror: musical third (e.g., E) from the front-right speaker

- Driver indicated completion by touching the screen
- Recognition of completion communicated by simultaneously illuminating all three icons and playing all three tones

Testing the Primary System

- For Version 2.0 development, testing different input methods, notification styles, and outputs.
- Input methods:
  - Single touch-screen button (whole screen)
  - Three touch-screen buttons, one per mirror
  - Single button on steering wheel
- Notification styles:
  - Notification only
  - Notification + Confirmation input (required)
  - Notification + Early confirmation input (optional)
- Outputs:
  - Various sound designs (octaves, tone duration, etc.)
  - Mirror icons vs. ambient illumination
  - Delay between chimes

Finalization and Discussion

- Following completion, testing of primary system, and testing with user population, the plug-in will be added to the IVAT program
- As more plug-ins are developed, integration of each will be investigated
- Process will also employ user-centered design to ensure entire program is usable and accomplishes its primary goals

- User-centered design allows this system to be made specifically for users
  - Therefore most effective at addressing their specific needs
- Employing UCD also allows for flexibility in future extensions of the plug-in
  - To other TBI users or separate populations (e.g. novice or elderly drivers)

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PERSONAS FOR ON-BOARD DIAGNOSTICS

USER TYPES OF DRIVERS DEALING WITH MALFUNCTION IN E-CARS

PräDEM

WHAT?

This work focuses on identifying user types of drivers dealing with malfunction in electric cars. Therefore, personas have been developed within the research project PräDEM (Predictive Diagnosis of Electric Motors in automotive drives).

WHY?

The personas served as a concrete design goal and means of communication for the development and evaluation of an ergonomically high-quality display and interaction concept for predictive On-Board-Diagnostics in electric cars.

HOW?

An expert round and four focus groups with drivers identified typical behavior patterns which were validated by surveys. As a result we got three personas of On-Board Diagnostics, which can be used for a more user-centered design of such diagnosis systems.

EXPERT ROUND
First rough classification of user types
Identification of behavioral variables & their values

QUESTIONNAIRES
Collecting quantitative data
Identification of behavior patterns

FOCUS GROUPS
Collecting qualitative data
Development of persona frameworks

SURVEY
Validation of persona frameworks

PERSONAS

DANIELA
THE PRAGMATIST

28, PR counselor
Professional field service
Expectations: flexibility, mobility, comprehensibility

„For me, my car is only an object of everyday use. On error, I just want to know how bad it is and what to do. The small error lights are absolutely cryptic for me.“

MIKE
THE CURIOUS

22, computer science student
Short-haul driver
Expectations: high information content, competence building

„I enjoy driving the car and I am interested in the technology behind it. I understand error messages of my car, but find them too little informative.“

RALF
THE ENTHUSIAST

34, Dipl.-Ing. Mechatronics
Commuter
Expectations: detailed diagnostic information, fix malfunctions by hand

„Cars are my passion, I screw for my life like. In general, I get myself information about malfunction by my diagnostic tester and fix it if possible.“

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ILMENAU UNIVERSITY OF TECHNOLOGY

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Natural, Intuitive Hand Gestures - A Substitute for Traditional DV-Control?

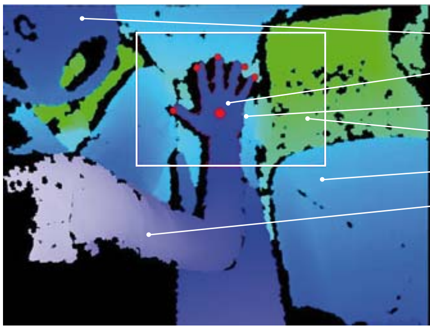
Research approach

- Driving and ADAS/IVIS operation is a complex visual-auditory task; overload/distraction affects driving safety
  → novel solutions for future vehicular interfaces are required to keep the driver's workload low
- Motion controllers (*Wii Remote, PlayStation Move, Kinect*) have revolutionized interaction with computer (games)
  → replacing button/stick based interaction with natural interaction based on intuitive gestures and body postures
- Mapping is „easy“ for games

...but is a highly competitive task for application in in-car UI's
→ body parts to be used? (*hand, arm, head, back*), region in the car (*wheel, controls, gearshift*), what are intuitive poses/ gestures?, which application(s) to control?, mapping command ↔ gesture?

Gestural interaction with an E-Mail client

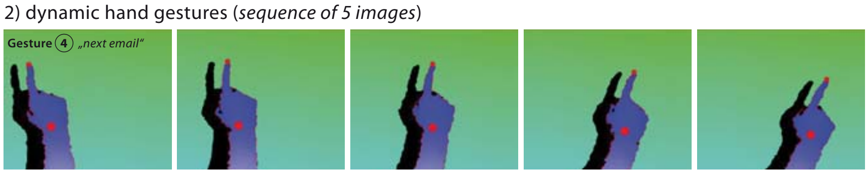
- **Predefinitions**
  - Driving in Europe (*cultural assignment; manual transmission*)
  - Highway situation (*free workload to process tasks; > 85% drive single handed on the highway (opinion survey)* → *gearshift area*)
  - Technique/sensory device (*RGBD images* → *Kinect*)
  - Application to control: Apply participatory design
    (step1; *ask business traveler*) → most votes for an E-mail client
    (step2; *ask freq. E-mail users*) → user defined mapping of hand poses/gestures



- **User study**
  - Visual request to perform certain pose/gesture (*in-car screen*)
  - Recognition rates of 0.98 for trigger task, ~0.90 for static poses, ~0.67 for dynamic gestures;
  - Only 10% deterioration under dual task condition (*auditory stimulus, cognitive/vocal response load as primary task*)

Selection of 1) static hand poses/gestures

2) dynamic hand gestures (*sequence of 5 images*)



Initial findings and issues to work on

- Volunteers liked this natural and intuitive type of interface and would like to see it in future vehicles
- Further research will address
  (i) Comparison of the gestural interface with conventional UI's based on button-/knob-control or speech input
  (ii) Replication of the tests under (more) real workload conditions, e. g., in a on-the-road driving scenario
  (iii) Customizable gestures (*based on driver's personal preference*) to achieve higher recognition rates, lower detection times

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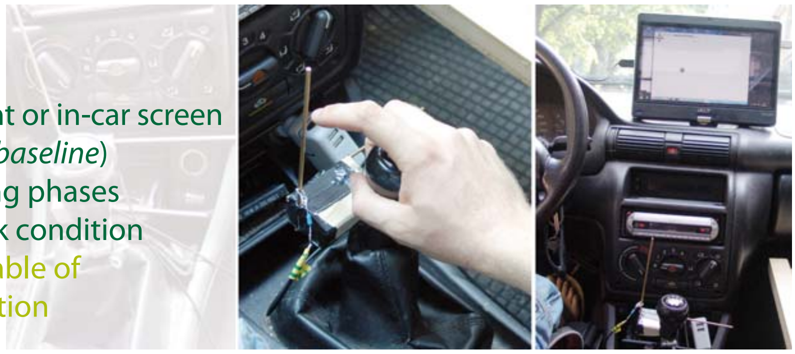
Technology for People

3D THEREMIN

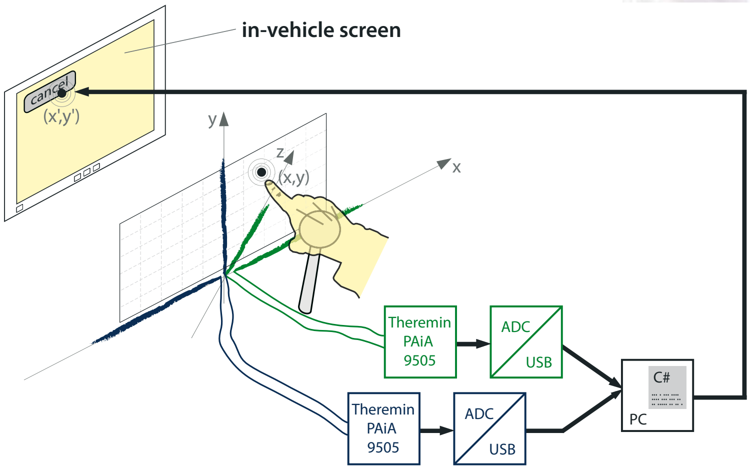
Convenient "Point&Click"-Interactions in Vehicles

Motivation

- Proximity sensing device: Theremin
- Allows mouse-like control in office environment or in-car screen
- Good performance in single task experiment (*baseline*)
- Increased performance even after short training phases
- Only little drop in performance under dual task condition
- Suitable device for implicit input, but not capable of "point&click" interactions or multitouch operation

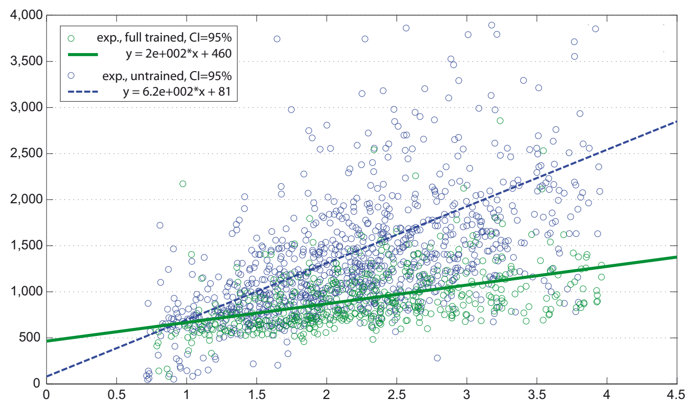


Application of the 2D theremin interface while driving.



2D→3D Theremin

- Extension with third antennae (*z axis*)
- Allows for "point&click" or "click&zoom" interaction
- *x* and *y* axis used for position estimation, *z* axis evaluated wrt. click actions



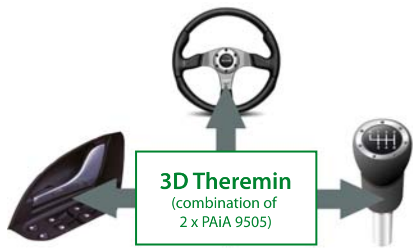
Significant rise in Fitt's law performance after a short training sesssion.

Major Benefits

- Independent from interfering light conditions
- Contactless user interaction (no extra device needed)
- Requires only little computational power
- Can be integrated into various objects (in-car use: on gearshift, steering wheel, electric windows, etc.)
- Universal use (mapping gesture - function/command)

Remaining Issues

- Interference between the 2 theremins (*4 antennae*)
- Filtering of "double coordinates" near the point of origin (*0; 0; z*)
- Optimization of click detection
- Visualization (*HUD, in-car screen, etc.*)
- Dynamic recalibration to stabilize cursor position
- Location of the interface in the vehicle
- (Long term) influence of the interaction on driver's cognitive load
- Capability of pattern recognition techniques to improve recognition rate and overall system stability



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SITUATION-ADAPTIVE DRIVER ASSISTANCE SYSTEMS FOR SAFE LANE CHANGE VIA INFERRING DRIVER INTENT

Huiping ZHOU, Makoto ITOH & Toshiyuki INAGAKI
University of Tsukuba, Japan

ABSTRACT

This paper focuses on driver intent inference by investigating driver glance behavior and driving maneuver, and attempts to show a general framework to design a situation-adaptive driver assistance system for avoiding a crash or an incident. The results show that inferring driver intent via monitoring driver glance behavior is not only to comprehend driver intent, but also important to detect if the driving performance is safe. The study revealed how to apply the intent inference for providing an appropriate support at a proper time point, which is expected to improve driver's acceptance and driving safety.

INTRODUCTION

- Approximately 25% of crashes were attributed to driver distraction [1].
- Drivers' recognition failure accounted for 65-75% of the lane changing/merging crashes [2].

Intelligent driver assistance systems have been developed for preventing such a distraction-related crash [3]:

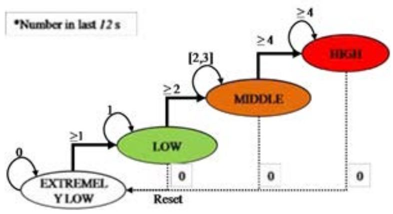
- Caution type
- Warning type
- Action type

Issue>> Selection of an appropriate type of support functions [4]

Purpose>> to investigate how to develop a situation-adaptive driver assistance system for changing lanes based on an inference of driver intent.

DRIVER'S LANE-CHANGE INTENT

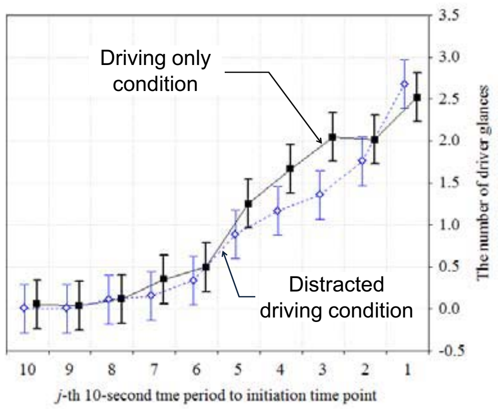
Inferring driver's lane-change intent [6]



EXTREMELY LOW: A driver has not recognized a slower lead vehicle or has not decided to pass the lead at all;
LOW: He/she has decided to pass the lead vehicle;
MIDDLE: He/she decided to pass the lead vehicle, but not determine to change lanes yet, and
HIGH: He/she determined to change lanes once the traffic conditions allow an implementation.

Distracted driver's lane-change intent [7]

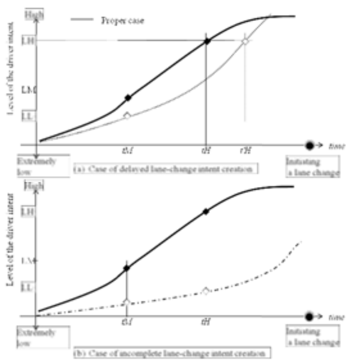
- Lane-change intent detection rate at HIGH level decreased but was not significant under distracted driving conditions in comparison with driving only conditions.
- Lane-change intent detection at each of levels was delayed significantly under distracted driving conditions in comparison with driving only conditions.



➤ Significant decrease of the glance behavior frequency under distracted driving conditions.

DEVELOPING AN ADAPTIVE DRIVER ASSISTANCE SYSTEMS FOR SAFE LANE CHANGE

Two cases of distracted driver's lane-change intent



Delayed intent creation

Driver's lane-change intent is detected at a delayed time point at each of level.

Delayed type might be caused by the reduction of the attention to the environment.

Caution type support function for enhancing driver's situation awareness should be suitable for the delayed case in order to re-attract the driver attention.

Incomplete intent creation

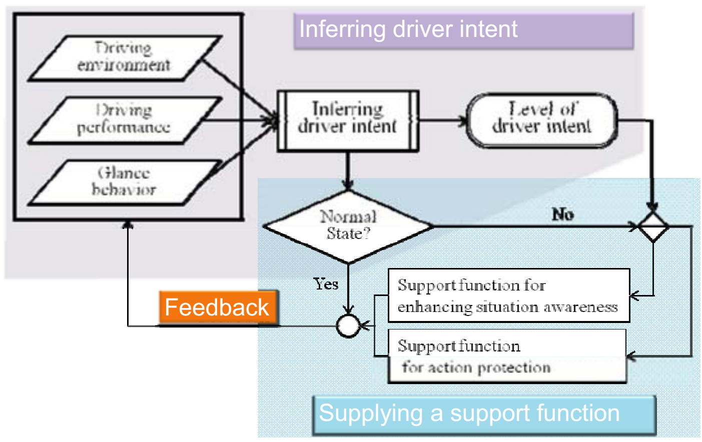
Driver failed to create the intent until changing lanes.

Driver distraction caused the failure in having the intent to change lanes rather than the degradation of drive situation awareness.

Warning message for evoking the situation awareness is given when a deviation from the appropriate driver intent creation.

Action protection function becomes essential if a driver ignored or missed the warning message.

Situation-adaptive support system for safe lane-change intent



Inferring driver intent

System processes environmental information, physiological information & driving information, and infers what a driver is going to do, and detects whether the driver is driving at a normal state and determines which level the current intent is.

Supplying a support function

System judges which kind of support function should be given adapting to the detected intent level once driver's cognitive state is detected abnormally.

Feedback

CONCLUSION

- This study presented how to apply the driver's intent inference for developing a situation-adaptive support system.
- The investigation implied that this adaptive function based on driver intent would be helpful to give a proper support function at a proper timing and to avoid an unnecessary support.
- Thus, the system will be expected to supply more comfort and effective function to a driver.

German Research Center for Artificial Intelligence

Daniel Braun, Christoph Endres, Christian Müller

Determination of Mobility Context using Low-Level Data

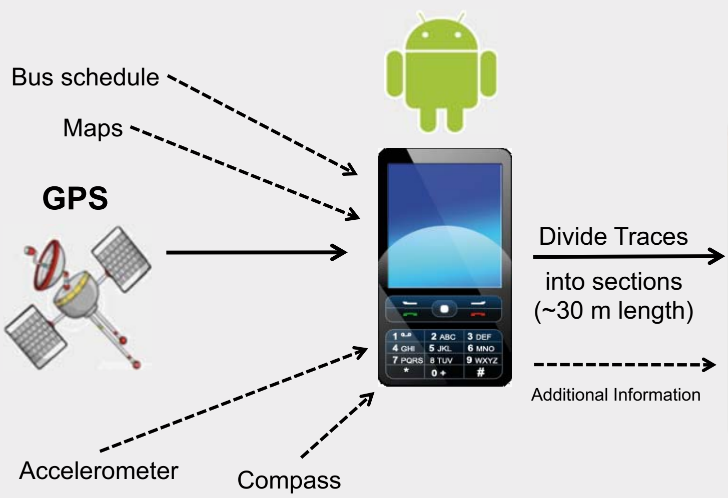
Motivation

- The mobility context strongly affects which information is relevant for a user.
- It can be used to adapt the way information is presented, e.g., in a car.
- It also can be used to calculate the carbon footprint of a user.
- Or can make suggestions for a more economic or ecologic way to work.

Why using Low-Level Data?

- Low-Level GPS Data are provided by every smartphone and navigation system
- The data can be used everywhere, because need road maps etc are not necessary
- The analysis of these data is easy and fast (realtime)

Approach




```
function calculateSpeed(){
        …
}
function calculateAcceleration(){
        ….
}

function contextHeuristic(){
        ----
}
```

Mobility Contexts

Different means of transportation :

- car
- train
- afoot
- etc

Different situations:

- urban traffic
- highways
- traffic jams
- etc

Result

Figure 1: Visualization of a trace using Google Earth. Correct determination of transportation means is depicted in green, incorrect results depicted in red. The recognition of the railway line in parallel to the highway is confused with driving by car.

Figure 2: Visualization of a trace with afoot parts. Incorrect (red) results are caused by inaccuracy of the GPS signal.

Figure 3: Visualization of a trip on the highway. Red parts are caused by traffic jams which are confused with walking.

Findings

We identified some areas with suboptimal recognition rates:

- Train rides can be confused with riding a car. (Figure 1)
- The recognition of walking is challenged by the inherent inaccuracy of the GPS signal. (Figure 2)
- Traffic jams are sometimes confused with walking. (Figure 3)

Conclusion

- **The use of low level GPS data as only source is not sufficient for recognizing the mobility context of a user.**
- It is necessary to connect the low level data with other information, such as street maps, schedules or additional sensordata (e.g., accelerometer) to obtain more reliable results.

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AutomotiveUI2011

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Salzburg, November 30th – December 2nd 2011

German Research Center for Artificial Intelligence

Sandro Castronovo, Monika Mitrevska, Christian Müller

Addressing Road Rage: The Effect of Social Awareness in Every Day Traffic Situations – A User Study

Introduction

- Online social networks have become common and broadly accepted
- These networks link people with a **"spiritual proximity"** but do not consider the **"physical proximity"**
- Millions of car drivers also form a social community but in contrast to traditional social networks, although they share the same "physical" proximity they lack the ability of communicating with each other ➔ no "spiritual" proximity.
- As a consequence, time pressure and anonymity often cause yelling, shouting and honking (often referred to as **"road rage"**)

- The extension to ad-hoc social road communities is at hand since the technical foundations are opening communication channels to each other and current research in the domain of vehicular ad-hoc networks is focusing this topic
- Question: Can we measure an effect on subjects' behavior by making the drivers **social aware** of each other?

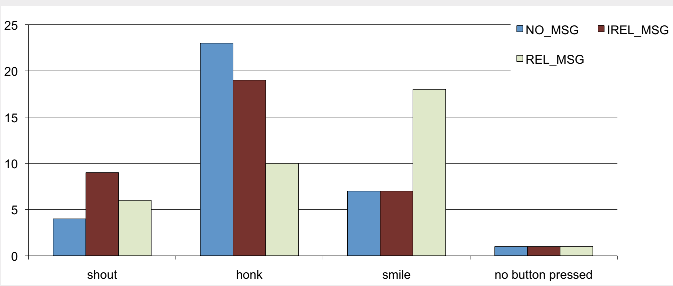
Experimental Study

- ***Subjects***
  - 18 subjects (6 female, 12 male), 19 – 40 years (average 26), valid driver's license and registered on facebook
  - Confirmation that the added application may use personal data
- ***Setup***
  - Driving scenario as facebook application. **Goal**: Reach destination within given time frame
  - 3 scenarios to slow the participant down: Traffic jam, slow car in front and blocked by not moving vehicle on traffic light
  - Use participants' facebook profile data to display **matching preferences** about driver in front (condition REL_MSG), arbitrary information (condition IREL_MSG) or no information (condition NO_MSG)
  - Only interaction possible: Honk, smile or angry comments by pressing one of the buttons ➔

f	Sample sentence
Birthdate	The driver in front is born on 24/03/82
Hometown	The driver in front is from Cologne
Education	The driver in front is an alumnus of Saarland University
Interests	The driver in front is interested in cats
Music	The driver in front is a fan of Madonna

Results

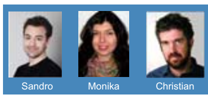
- No message presentation (condition NO_MSG) resulted in more frequent aggressive driver reaction
- Presentation of general messages, e.g. no match to the personal preferences of the participant according to their social network profile, gave similar results (condition IREL_MSG)
- Presentation of messages which match personal preferences of the participants resulted in a shift from shout and honk to smile
- **Statistical analysis**
  - Nominal scaled data ➔ Chi-squared test
  - Aggregation of shout and honk ➔ negative reactions, smile ➔ positive reaction
  - Comparing REL_MSG to IREL_MSG ➔ $\chi^2(1) = 8.10$, $p < .01$
  - Comparing REL_MSG to NO_MSG ➔ $\chi^2(1) = 7.65$, $p < .01$



Conclusion & Future Work

- We presented a user study which investigated the effect of social awareness on road rage in three different driving situations
- We measured the reaction of participants when altering the situation in terms of messages with or without personal information about the car driver in front or no message at all
- We used data available from the subject's social network page since asking obvious questions in advance would compromise the results
- Our results indicate that spiritual proximity has a positive effect on the driver's interactive behavior in cases of physical proximity
- They also indicate that already existing information in social networks can be used to realize matching personal preferences
- **Next steps**
  - In order to confirm our results, a **follow-up study** with the results of this paper will be conducted. We will then **distribute** the system as a game **in a large social network**
  - Results will influence design and implementation of an in-car social networking application on the basis of V2X

This preliminary study → Large-scale study using a social network → In-car application using existing profiles



Sandro Monika Christian

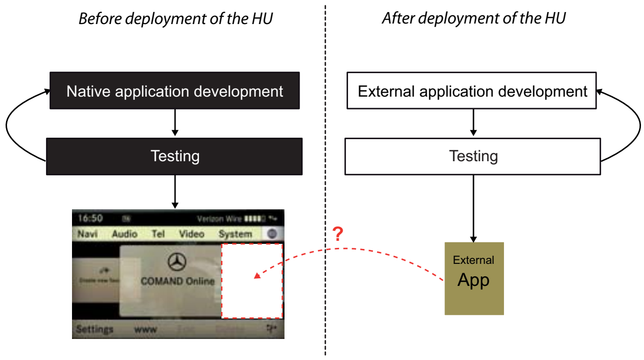
This work was funded by the German Federal Ministry of Education and Research

DAIMLER

New Apps, New Challenges: Quality Matters in Automotive HMI Development

Mark Poguntke, Daniel Mauser

Motivation



- Increasing spread of mobile applications
- Desire to bring mobile, external applications to the car
- Interdependency between native in-car application development and external application development, integration and testing

Example Use Case

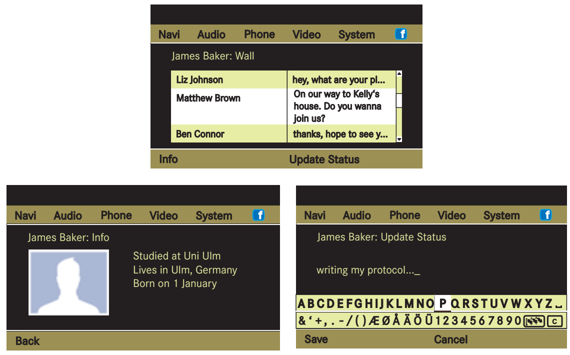
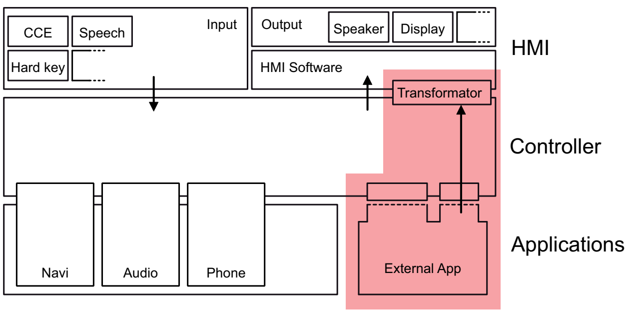


Illustration of an external Facebook application integrated on the basis of an existing Mercedes-Benz HMI concept at runtime

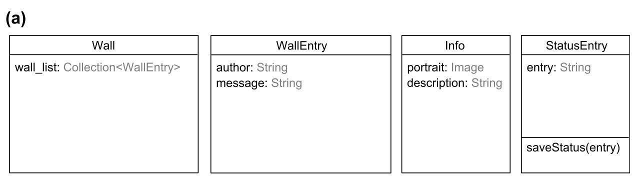
System architecture

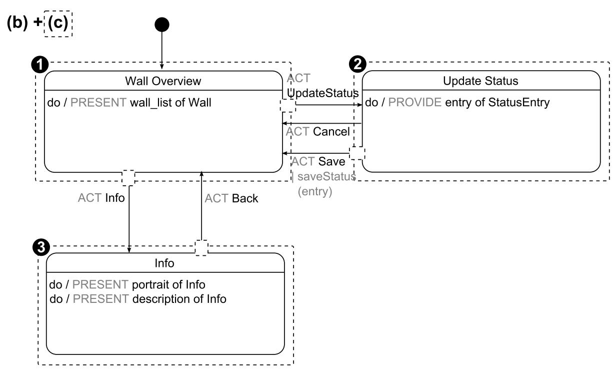


- *HMI*, *Controller* and *Applications* levels
- External Applications have to be connected to the *Controller* level via defined interfaces
- On *HMI* level the UI model of the external app is transformed by the HMI software to the target HMI

Approach

- Abstract UI model of external application based on class diagram (a) and state machine (b)
- Mapping of model elements to pre-defined and pre-tested GUI components (c: 1,2,3)





Conclusion

- Approach enables a process that allows correct HMI integration of external applications at runtime
- Either a valid combination of pre-tested GUI components can be found or the external application is not supported

AutomotiveUI'11, Nov 29 - Dec 2, 2011, Salzburg, Austria.
Please see the paper for more information and references.

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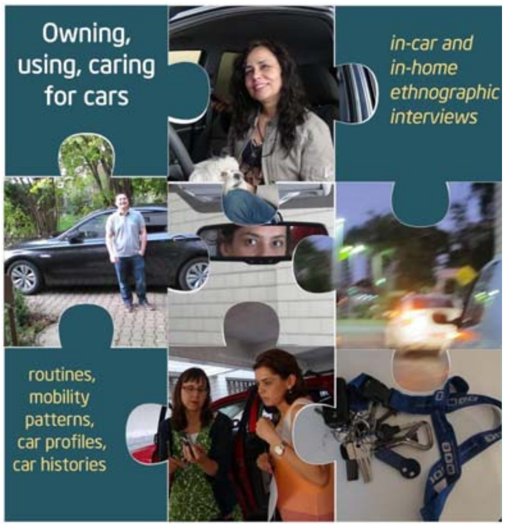
The Ethnographic (U)Turn:
Local Experiences of Automobility

A six country multi-method exploratory research study that faces the complexity and diversity of existing car experiences head on

A turn away from the increasingly common assumption in corporate settings that ethnographic research is simply 'talking to people'. As in classic ethnographies of the early 20th century, this study employs an array of systematic qualitative & quantitative approaches, integrated to create multi-faceted portraits of lived experiences.



Local Experiences of Automobility creates a design space for smart transportation futures that will be differently realized in various markets. Successful solutions must reckon with and adapt to 100+ years of locally realized infrastructures of roadways and traffic systems including legal ,regulatory, safety and surveillance systems, and deeply embedded local driving practices.

Alex Zafiroglu, Tim Plowman, Jennifer Healey, David Graumann, Genevieve Bell, Philip Corriveau
Interactions & Experience Research

(C)archeology
Car Turn Outs & Automobility

What is a car? What does it mean to own a car? To use one? To care for one?

Our objective:

To see cars with fresh eyes: to think about them as a field site in and of themselves, and as an object of study

Our Tools:

a tarp
folding step stool
cameras

Our Excavation Locations:

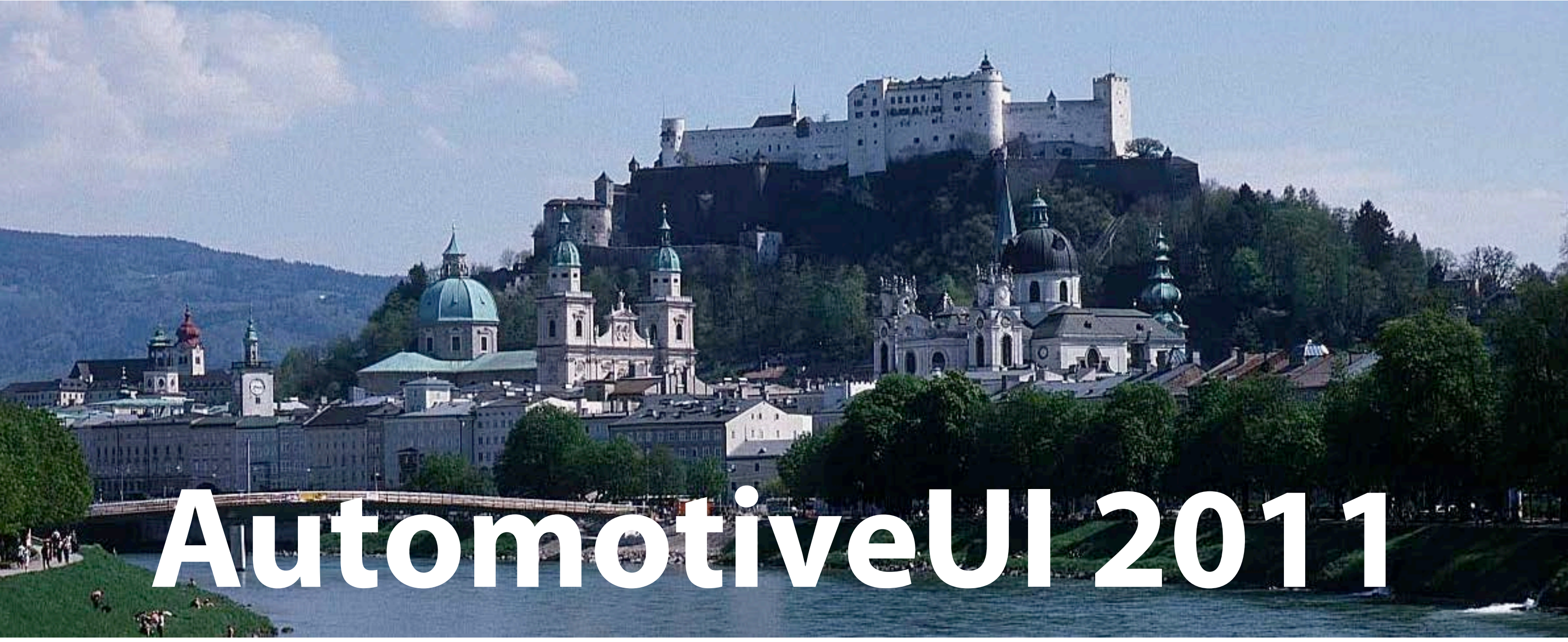
privately owned passenger cars in the US, UK, Australia, Singapore, China, Malaysia, Brazil and Germany

Frankfurt & Munich

hidden bounties in trunk recesses

Singapore & Penang

convenience and consumption



Third International Conference on Automotive User Interfaces and Interactive Vehicular Applications

November 29—December 2, 2011
ICT&S Center, University of Salzburg
Salzburg, Austria

Adjunct Proceedings "Industrial Showcase"

Organizers:

Manfred Tscheligi	Conference Chair
Albrecht Schmidt	Industrial Showcase Chair

Dialogs Are Dead, Long Live Dialogs: Building a Multimodal Automotive Application for Both Novices and Experts

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ABSTRACT
We describe a prototype car navigation system with a high level of sensitivity towards the differing abilities of users and the differing levels of visual and cognitive demand in real-world driving. The system, called VoiceCar, supports conventional, step-by-step, mixed-initiative voice dialogs and commands as well as more open-ended, entirely user-initiative interactions (which we term "anti-dialogs"). Much validation work remains to be done, but we hope that our demonstration system's support for both dialogs and anti-dialogs makes it more adaptable to a variety of driving situations, to users of all levels, and to ill-defined or shifting user intentions.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Graphical User Interfaces (GUI); Interaction Styles (e.g. commands, menus, forms, direct manipulation); Voice I/O

General Terms
Design, Human Factors

Keywords
Multimodality, dialogs, speech dialog systems

1. INTRODUCTION AND RELATED WORK
There is ample evidence that speech-based interaction with in-vehicle information systems (IVIS) improves such critical driving behaviors as lane keeping and reaction time as compared to manual interactions with the same systems (e.g., [1][3][5]). However less attention has been paid to multimodal (often speech + tactile) systems, or to driving situations that vary in cognitive or psychomotor demand levels over the course of a driving session. Castronovo et al. [2] found that both multimodal and speech-only control of HVAC functions resulted in less deviation from the ideal lane position than the use of a rotary knob alone, but their study was carried out using the highway Lane-Change Task [6], which is fairly uniform in nature (in terms of vehicle speed and maneuvers required).

Despite the findings cited above regarding voice interfaces' benefits to drivers, might there be certain road or traffic conditions in which manual input is more appropriate or even safer than voice input (especially considering the sometimes detrimental effects of recognition errors, when they do occur [4])?

Perhaps a mix of the two modalities is the most practical option. When one hand can come off the steering wheel and there is time for quick downward glances, users may prefer the simple efficiency of a touchscreen or knob. In heavy traffic or while actively maneuvering, however, reliance on the voice user interface (VUI) seems to make more sense.

It is this pragmatic, "best tool for the job" philosophy that has inspired the design for VoiceCar. We will introduce the system briefly in the following sections, but we hope the reader will also attend the demonstration of an early iteration of the system.

2. SYSTEM DETAILS
2.1 Voice and Multimodality
As one might guess from the prototype's name, speech is a first-class modality in VoiceCar rather than merely a supplement to tactile and visual interaction. All screens and functions of the application can be accessed by spoken commands or searches, and synthesized or recorded voice prompts announce all important changes of state. However, visible text and graphics play equally important roles (as will be further explained below), because users generally can comprehend the results of a search or command more quickly by reading than by listening.

2.2 Platform
VoiceCar is built on top of Nuance's production embedded application framework, meaning it can leverage all of the core automatic speech recognition (ASR) and text-to-speech (TTS) engines' advanced features (such as natural language understanding and multilingual acoustic models). Noise robustness and broad language and dialect coverage also come "for free" in this sense. Meanwhile, the use of the production framework means that VoiceCar's advancements in the application tier (e.g., in dialog and grammar design and in GUI/VUI integration) can more easily cross-pollinate customer projects. This means that although VoiceCar is primarily a research and sales tool, there is very little "throwaway" work.

The application framework is written in standard ANSI C, so we wanted a graphics toolkit with nearly as wide an array of porting options, but one which also offered a robust Model-View-

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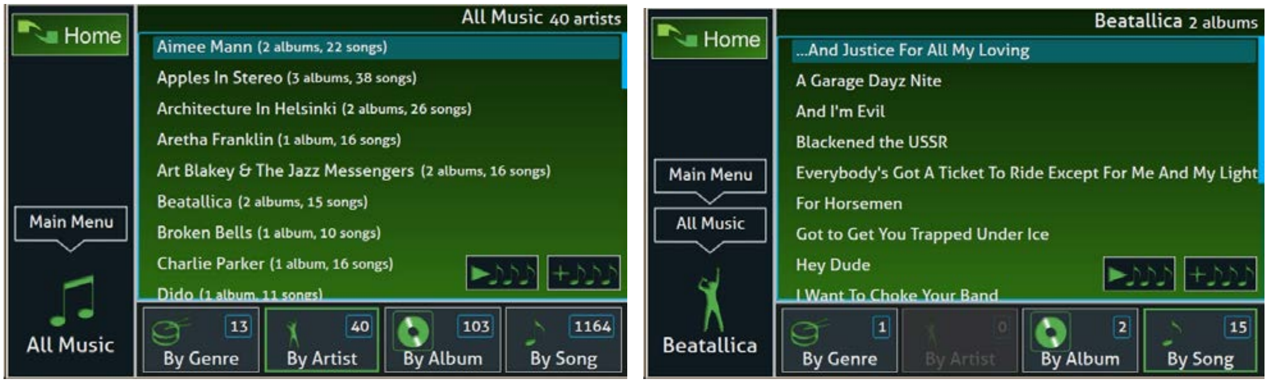

Figure 1. All Music and filtered views. Notice the "breadcrumb" bar at left to orient the user as to where she is in the application hierarchy and to enable instant access to historical states.

Controller paradigm and high-level support for animations. For this reason we chose the AIR runtime and the Flex component model from Adobe. While the initial demo target is a Windows PC, the choice of Flex and AIR will allow us to support, for example, Android tablets and the iPad in the future with minimal rework.

2.3 Feature Set

While we intend to extend the prototype to eventually encompass most of the functional domains in a modern navigation system, for time reasons we are focusing initially on the music domain.

2.3.1 Local Music Access

On startup VoiceCar indexes the contents of attached USB devices and a designated folder on the hard drive, and it builds a relational database of the genres, artists, albums and songs present. The music content can then be accessed in two different ways:

2.3.1.1 Hierarchical Browsing

This style of interaction works well for users who don't know precisely what they want to hear, or who aren't sure whether a particular song or album by a given artist has been copied to the device. In this paradigm a typical voice command sequence might be "Music," then "By Genre," "Jazz," and "John Coltrane," or perhaps the three-step sequence depicted in Figure 1.

2.3.1.2 One-Shot Searching

VoiceCar also allows users to at any time issue one-shot commands like "play X" or "play X by Y," where X and Y correspond to words from any field in the music metadata store.

2.3.2 Remote Music Access

At the same time as the "play X by Y" command is processed by the local, embedded ASR instance, the captured audio is encoded and streamed to a server-based recognizer with a wider vocabulary and a more relaxed language model. When both results come back, if the embedded result has a sufficiently low confidence score attached to it, it is deduced that the command likely referred to music not present in the local collection. The remote result is parsed instead for artist, track, and/or album tags, and the GUI's streaming player is launched.[1]

3. USABILITY AFFORDANCES

VoiceCar accommodates different types of users (novice to familiar to expert) and different contexts of use (e.g., congested urban driving interspersed with occasional stops at traffic signals). It does so by allowing modality cross-over during interactions and by supporting different initiation and pacing strategies for multi-step voice input.

3.1 Modality Cross-over

Envision a harried urban driver who has been carrying out a step-by-step hierarchical browsing interaction using speech, but she is now pulling to a stop at a traffic signal. For subsequent steps in the interaction, she can simply switch to the touchscreen or rotary knob without any need to restart at the root of the hierarchy. Conversely, if a previously uncrowded highway suddenly becomes congested due to construction or an accident, a VoiceCar user who has begun an interaction using the touchscreen can conscientiously put both hands back on the steering wheel, press the push-to-talk (PTT) button, and continue the interaction by voice.

3.2 Dialogs

3.2.1 Background

Mixed-initiative voice dialogs are those in which the pace of the interaction is controlled by the system once the initial PTT button press has been received. Once the user initiates the dialog via PTT press, the system takes control of the pace. Typically it plays a recorded or synthesized prompt to explain what kind of input is expected, then immediately it plays the listening beep and opens the microphone for input. The interpretation of this input may trigger another immediate prompt/beep/response cycle, either for traversal into a deeper node of the menu hierarchy or, for example, to obtain a Yes/No confirmation or a selection from an N-best result list.

System-paced interactions like this are standard in the industry today, and many experienced users prefer them, because

[1] Currently Grooveshark (http://grooveshark.com) streams are supported, but we plan to support other streaming services in the future.

unnecessary PTT button presses are avoided and the overall duration of the multi-step interaction is kept as short as possible. However, those new to speech dialog systems, or those new to a particular dialog and grammar implementation, may have trouble understanding what they can say or when it is their turn to speak. Consequently they may issue an invalid command, or keep silent entirely while they try to think of a valid command. Meanwhile the system will notice their silence and re-prompt them with a phrase like "I didn't get that," which may make the user feel nervous or uneasy.

3.2.2 Kinder, Gentler Dialogs

VoiceCar supports system-paced dialogs because of the efficiency advantages mentioned above, but makes two subtle tweaks to their behavior that we feel improve their suitability for novice users and/or stressful driving situations.

Firstly, the delay between iterations of the prompt/beep/response cycle—between steps in the dialog, effectively—is configurable within the GUI. Expert users who do not need even a quick glance to the screen to confirm their expectations might set this delay between zero and one seconds, whereas speech UI novices or those experiencing the system for the first time might prefer a delay of two or three seconds (or even longer).

Secondly, due to the parallel data models of GUI and VUI, and the seamless modality cross-over described above, users feel less stressed and less rushed to respond "before it's too late." A silence timeout from the speech recognizer does not mean any lost progress; after one or two silences (this is configurable) the system simply plays a "pausing" earcon and closes the microphone. Interaction can then be resumed as soon as driving conditions allow, either via a purely tactile affordance or via PTT plus speech.

3.3 "Anti-Dialogs"

Even with these behavior tweaks, some users might prefer to turn dialog auto-advance off completely, in other words to set the delay between prompt/beep/response cycles to infinity. This results in an interaction paradigm one could call an "anti-dialog," where the user carries out the discrete, individual atoms of an interaction entirely at her own pace, pausing, considering, and perhaps back-tracking before eventually accomplishing the task she set out to accomplish.

Or perhaps—more interestingly—accomplishing a different task than the one she originally had in mind, due to the vagaries of mood or inspiration. Music-domain tasks are particularly susceptible to these sorts of swings of intent. People quite frequently begin browsing their collections with one thing in mind, and then end up choosing something completely different. Going in with a vague desire for Joni Mitchell and coming out convinced you want to hear Regina Spektor is the kind of "happy accident" that couldn't happen with a traditional music dialog (and is probably the only happy accident you'll ever have in a car!).

4. FUTURE WORK

We plan to expand VoiceCar to cover more functional domains, including hybrid (embedded/cloud) Point of Interest search and SMS dictation. Also on the horizon is integration with Nuance's handwriting recognition technology, as we are seeing more cars that incorporate touchpads into their HMI.

Before we get too far with functionality enhancement, however, it would behoove us to conduct one or more usability studies in driving simulators or instrumented vehicles in order to vet our assumptions regarding ease of use and suitability across different user groups and driving scenarios.

5. ACKNOWLEDGMENTS

There are too many contributors to acknowledge everyone by name, but some particularly vital work has been done by Lars König, Andrew Knowles, Rick Megley, Daniel Regert and Slawek Jarosz of Nuance and by Björn Kunz and Sandro Castronovo of DFKI, our GUI partner for this project.

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Using Controller Widgets in 3D-GUI development with end-to-end toolchain support

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ABSTRACT

Customer expectations are growing and so are technological advances. This calls car manufacturers to develop increasingly complex graphical user interfaces (GUI) in ever shorter time periods and within unchanged budgets. Efficient processes are required that are supported by specialized tools end-to-end. Conventional tools for model-based GUI-development are based on widgets, whose graphical appearance is programmed manually. This means that during implementation of the final software the design drafts that visual designers create have to be rebuilt manually, as the necessary widgets have to be identified, implemented and used to compose an identical-looking GUI. Such approaches are inefficient and delay the adoption of new GUI designs. They become even more problematic when creating three-dimensional GUIs.

The paper presents a solution to overcome this problem by reducing the widgets to controllers, which don't have a specific appearance. That allows using standard graphics editing programs to create the visual design of the GUI, which is then imported into the tools applied to create the final software. The developers use the widgets available in those tools to connect the application logic to elements of the imported designs. They can manipulate existing graphical elements and trigger existing animations at runtime. This approach allows integrating the designer's and the programmer's tools seamlessly.

Categories and Subject Descriptors

D.2.2 [**Software Engineering**]: Design Tools and Techniques – *evolutionary prototyping, user interfaces;* D.2.6 [**Software Engineering**]: Programming Environments – *Graphical environments*; D.2.9 [**Software Engineering**]: Management – *Programming teams;* D.2.m [**Software Engineering**]: Miscellaneous – *Rapid prototyping*; H.5.1 [**Information Interfaces and Presentation**]: User Interfaces – *Graphical user interfaces (GUI), Prototyping, Screen design;* I.3.4 [**Computer Graphics**]: Graphics Utilities – *Graphics editors, Software support;* I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism; I.3.8 [**Computer Graphics**]: Applications; J.9 [**Computer Applications**]: Computer in other systems – *Consumer products.*

General Terms

Management, Design, Human Factors, Standardization, Performance.

Keywords

User Interface, HMI, GUI, 3D-GUI, Automotive, Cluster, Infotainment system.

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Adjunct Proceedings.

1. BACKGROUND

An appealing and user-friendly design of the human-machine interfaces (HMI) is an important parameter for the success of consumer products in the market [1]. This also applies in the case of automobiles, which are equipped with increasingly powerful hardware that enables the introduction of new software based features for entertaining and informing the passengers. Despite the fact that the range of these functions is continuously growing, users demand simple handling and an appealing graphical design of these systems. Furthermore, user expectations from the rapidly evolving consumer-electronics market carry over to the automotive one. This fact, along with the shortened lifecycles of automobile generations, leaves very little time for developing complex HMIs.

Car manufacturers (OEMs) continually extend their product portfolio by adding new models that have to be differentiated from each other. One way in which this is achieved is by altering the customer perceptible parts such as the HMI software. This leads to a need for developing a growing number of different complex HMI software variants in even shorter time periods [2,3]. The high product quality that is essential to automotive applications has to be assured and not sacrificed because of the short development cycles. In order to achieve this OEMs have to continuously optimize their HMI development processes (Figure 1).

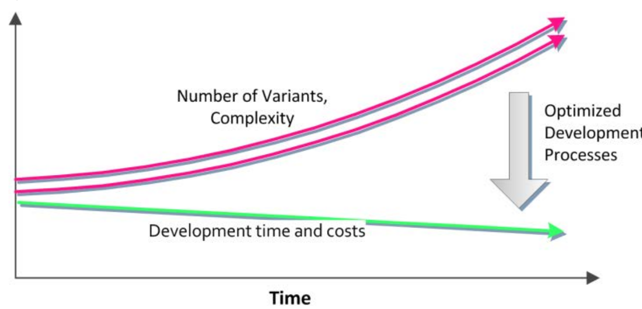

Figure 1 – Rising complexity number of variants vs. available development time and costs

1.1 Iterative-Parallel Development Processes

Since the available development timeframe is considerably shortened the individual development steps cannot be carried out in a strictly sequential manner. Instead, they have to be worked on in parallel. In order for the system to match the user's expectations early HMI prototypes have to be repeatedly evaluated in customer clinics. For this reason the development processes need to be structured iteratively to allow for incorporating the evaluation feedback.

The visual design of the graphical user interface (GUI) plays an important role for building appealing products. Visual designers often need to adapt their drafts for the GUI multiple times throughout the development process in response to feedback from customer clinics, changes in requirements, or adhering to latest market trends. Once the implementation of the final HMI software has begun such design changes need to be integrated with minimum effort.

1.2 Conventional and Model-Driven HMI Development Processes

The HMI prototypes and the final HMI-software for the target system can be created using different approaches based on cooperation between OEM and first tier suppliers. In the usual division of tasks the OEM is responsible for creating specifications that serve as a basis for a call for tenders. The supplier manually implements the final software based on this specification (Figure 2).

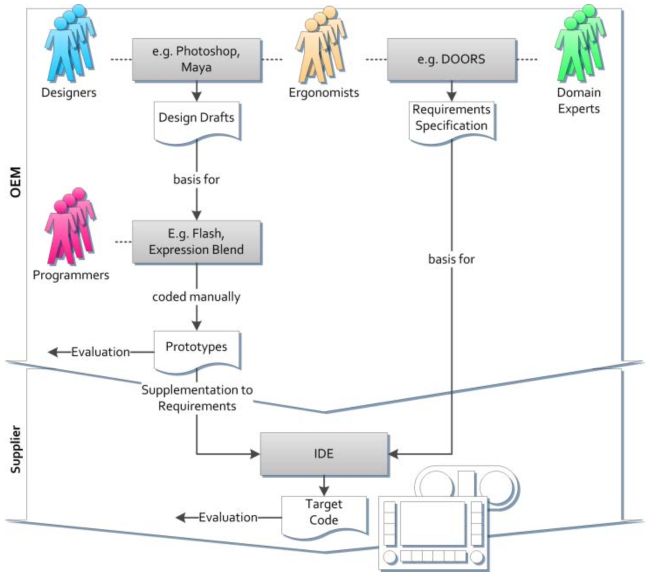

Figure 2 – Conventional HMI Development Process

The manual implementation involves a great deal of financial expense and time. This is why HMI prototypes based on the target hardware are available for evaluation very late. Until then the OEMs have to develop prototypes for management presentations and customer clinics, but not on the target hardware. The source code of these prototypes cannot be reused as it is not scalable, does not meet the requirements of the target systems and may be based on unsuitable technologies[1]. Additional prototypes that use close-to-series hardware and software are vital for evaluating user experience aspects such as the look-and-feel of animations. However, if the HMI software is implemented manually the supplier can only provide such prototypes in late stages [4]. In the remaining time the OEMs can perform only a small number of iterations. All resulting corrections have to be performed manually, which is particularly costly when done in these late stages [5].

A major part of the HMI specification serves to describe the system's graphical design with pixel accuracy. The usage of conventional requirement formats is unsuitable for this purpose. The effort to create such specifications for modern HMIs is very high because it is difficult to describe things like animations and the dynamic layout of the GUI. In order to complement the HMI specification documentation, OEMs can give the prototypes that they have created to the supplier. However, this means that the OEMs have to spend effort on maintaining and extending these prototypes throughout the development process.

Model-driven approaches can be applied in order to avoid the drawbacks of the manual implementation (Figure 3). The basic idea is to specify the HMI in a machine-readable form using formal models. These models are executed by code generators or interpreters [6]. This allows for updated prototypes to be created right after changing the source models. HMI prototypes are available for evaluation without expensive and time-consuming manual programming [7]. The shortened turnaround time yields more iteration cycles during the same period of time and thereby achieving a higher quality of the final product.

Furthermore, the model-driven development processes boost the OEM's flexibility because they enable major modifications to be made to the HMI even in late development phases [8]. The automated processing prevents misunderstandings due to wrong interpretation of the models [9]. The prototypes created by the OEMs can be passed to the supplier to serve as reference for implementing the code generators or interpreters for the target hardware.

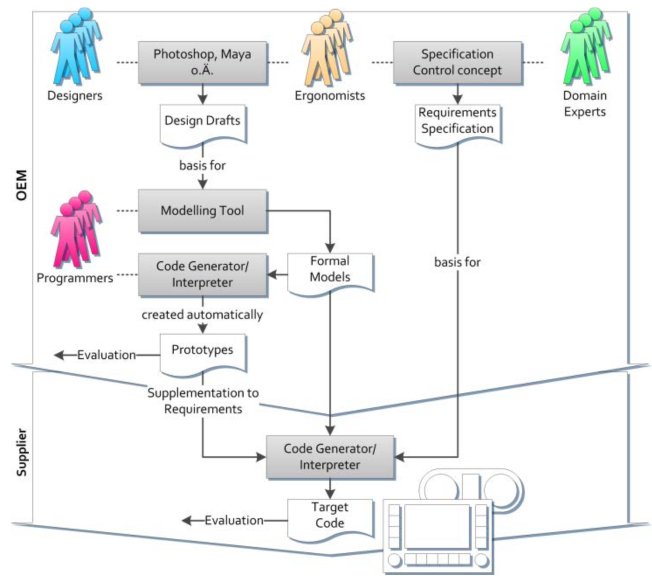

Figure 3 – Model-Driven HMI Development Process

2. CURRENT STATE OF THE ART

The advantages of model-driven HMI development are well known in the automotive domain (e.g. [10]) and the corresponding processes are applied in industrial practice. However, a model-driven approach requires the availability of adequate model types and tool support for their creation and processing. The most important tools and scientific approaches which are used in the automotive domain and are available on the market today are presented below. Furthermore the problem of adopting updated GUI designs as well as the associated drawbacks of each tool is discussed.

[1] These prototypes are often based on Adobe Flash. However, no sufficient support for this technology is available for all target platforms so far.

2.1 Modeling using Conventional GUI-Builders

Bock [1] proposes that OEMs define suitable model types and create the corresponding tools by means of Meta-CASE tools[2]. His sample implementation is divided into separate views, each of which is addressing a different expertise (layout, content, and behavior). Graphical models based on Statecharts [11,12] are used to describe the HMI behavior. A standard SWT/Swing GUI builder is applied for modeling the layout of the GUI, which is intended to be used by visual designers. In such tools the GUI is composed of multiple views that consist of a hierarchical structure of SWT- or Swing-widgets. Each instance of a widget in a view can be individually configured by adapting its properties. However, the look and feel of the widget types needs to be programmed manually.

Choosing such a GUI-builder is not reasonable because these graphic frameworks are not used in embedded target platforms. They are designed for desktop applications and are not suitable for building HMIs for consumer products. Another major drawback of all conventional widget-based GUI builders is that each type of widget needs to be programmed manually before it can be used for modeling. When visual designers want to create new GUIs the available widget set may not be sufficient for their implementation. All additional widgets have to be created before they can be used to build the GUI. This leads to delays and acts as a break on the creative design process. A further drawback of this approach is the fact that the widgets developed using SWT-/Swing technology cannot be used in the target system but have to be re-implemented using other technologies. This leads to considerable additional specification and implementation effort because the widgets constitute an essential part of the GUI's look and feel. Finally, since the same functionality is implemented more than once it can no longer be assured that prototypes and the final HMI show the same appearance and behavior.

2.2 Available Tools for HMI Modeling

There are several specialized tools available on the market for creating HMI models and transforming them into executable software for embedded systems [13], e.g., *Elektrobit's Graphical User Interface Designer Studio (GUIDE)* [14,15], *Presagis' VAPS XT* [16,17,5], and *Mecel's Populus*.

All these tools are designed for the model-driven development of automotive HMIs. They are applied to formalize and detail drafts of ergonomists, visual designers and other domain experts. The tools make use of different specialized editors. Code generators and runtime environments create prototypes and the final HMI-software for the target system respectively.

In order for the editors to be easy to use without experience in programming, they make use of graphical notations and the WYSIWYG system. These tools however, are quite complex so in practice are used exclusively by trained experts.

In these tools modeling the GUI is also based on widgets just as in the GUI-builders for desktop applications. Therefore, all necessary widgets need to be implemented before they can be used to build the GUI. This is a major drawback, because it is often the case that changes need to be made to the design of the GUI in late project phases due to influences from evaluation feedback or new design trends. These changes may call for new widgets to be made, which need to be precisely described by the visual designers and then implemented by programmers. This results in associated efforts for both. When those widgets are available they are used to rebuild the draft of the designers as exact as possible. This procedure delays the development process because the same visual designs are implemented twice using different technologies.

2.3 EDONA-HMI

The EDONA-project addresses the interoperability of the tools applied in the development of automotive embedded systems [18,19]. An integration platform was developed which allows exchanging data or models between OEMs and suppliers. A subproject of EDONA focuses on the model-driven development of HMIs [9]. If the models exchanged between OEMs and suppliers use formats tied to a certain tool, the suppliers are forced to adapt their toolchains whenever the OEMs change their tool [19]. Based on this observation, EDONA HMI proposes to make use of a tool-independent exchange format. In the past multiple such formats have been developed[3]. Most of them are specific XML-based languages. However, because none of these have become an industry standard tool support is not widely available. EDONA HMI, however, recommends using the already established image format SVG. In SVG an image is composed of a tree of primitive graphic objects (scene graph). EDONA HMI defines a specific SVG subset (profile) adapted to the need of automotive HMIs. The profile also introduces particular extensions that can be used to annotate attributes of elements in the scene graph, such as the position or angle of an object. These annotated attributes can then be connected to calculation rules which modify them at runtime based on data coming from the application[4]. The calculation rules are described using the ESTEREL synchronous programming language. SVG files and their calculation rules can be bundled into HMI components. Similar to widgets, they serve as reusable building blocks consisting of graphical appearance and behavior.

Even though using SVG files is advantageous as mentioned above the format is not used as exchange format in industry. However, the approach of going with a standard graphic format is wise because it allows for seamless integration of the HMI modeling tools and the tools which visual designers use. Designers can create design drafts using standard software without having to use a specific tool. These drafts can be used directly for the implementation of the final HMI software instead of having to re-create them using a particular widget set. Modern GUIs use complex animations that are also defined by visual designers. SVG files however cannot describe animations so this information cannot be exchanged. Furthermore, the SVG format supports only 2D graphics and not 3D GUIs, which are foreseen to play a big role in the next generations of automotive HMI [14,20,21].

The low familiarity of ESTEREL in industrial practice is also a drawback of EDONA. Furthermore, the way ESTEREL is used in is not sufficient for defining the complete behavior of the HMI. For example, it cannot describe the dialogue flow including

[2] The term Meta is used for a class-instance relationship between different models. Analogous to this, tools that serve to create CASE-Tools for individual model types are often called Meta-CASE-Tools.

[3] Examples of such formats are OEMXML, VWXML, IML, ICUC-XML, and Abstract HMI.

[4] To create a virtual analogue gauge a SVG image is required. The needle's angle attribute is then annotated and linked to a rule that calculates the angle based on an input signal.

multiple views or how the individual HMI components interact with each other within a single view.

3. WIDGETS IN 3D-GUIs

Conventional widgets for 2D GUIs come with a pre-defined look. This look is defined in a drawing routine that renders a widget instance to a given canvas object while taking into account the current state of the widget. However, this approach is not suitable for 3D GUIs. In such GUIs the user interacts with objects in a three dimensional space. These objects might look partly transparent and can intersect or illuminate each other. As a consequence, a single widget cannot draw itself independently because its appearance is influenced by other objects. A central renderer is needed to handle the overall rendering taking all objects into account.

This calls for new concepts in widget implementation. A possible solution would be to modify the widget's drawing routine to report the objects that reflect its present state to the central renderer. The central renderer would then perform the rendering of the scene after it has collected this information from all widgets. In this approach the look of the widget is defined programmatically just like with conventional 2D widgets. As previously described this leads to duplication of work which makes design changes costly and time consuming.

Having a central renderer that knows the complete structure of the scene in the form of a scene graph is the key to implement 3D GUIs. Moreover, it can also be useful in conventional 2D GUIs because it also enables implementing appealing effects such as camera movements or filters.

4. CONTROLLER-WIDGETS

In order to be able building seamlessly integrated toolchains it makes no sense to dictate visual designers what tool they have to use to create design drafts. GUI builders in particular offer limited capabilities compared to professional graphic editors and therefore hinder the creative process. Furthermore, it is more difficult to try out different design variants using such tools because the widgets required for each variant have to be implemented beforehand. Instead, visual designers should be able to use tools that offer maximum design possibilities without being restrained by implementation details. Ideally, standard graphics editing programs can be used such as Adobe Photoshop or Autodesk Maya.

Analogous to the approach proposed in EDONA, the designs created in these tools should be saved to a standard format which then can be imported to subsequent tools and reused for the implementation of the final HMI. However, in order to be applicable in the development of three dimensional GUIs, too, other image formats than SVG have to be used. In addition to the static GUI layout the format should also include animations. COLLADA and FBX are examples of formats that can match these requirements.

After the GUI has been imported into the HMI development tool it is represented as a scene graph. This scene graph can be supplemented with technical information that are not relevant for the graphical design but are required to implement an efficient rendering in an embedded system. Such information cannot be imported because they are not specified by the visual designers.

Up to this point in time the imported GUI design is still static. Widgets can be used to make it become dynamic. In this case the widgets serve as reusable components of HMI behavior that can be configured using the widgets' properties. Just like in conventional GUI builders these properties also define the interface between the GUI and the application logic. However, the appearance of these widgets is not programmed. Instead of that, the widgets are assigned to elements of the imported scene graph. They can manipulate these elements according to their current state. As a result, programming widgets is reduced to the definition of this behavior as well as its properties for parameterization and data exchange with the application. Instead of using ESTEREL other programming languages for embedded systems should be used that are familiar to more developers.

With regard to the popular model-view-controller pattern[5] [22] the widget's task is reduced to the controller-role while the view is derived directly from the visual designer's drafts (Figure 4).

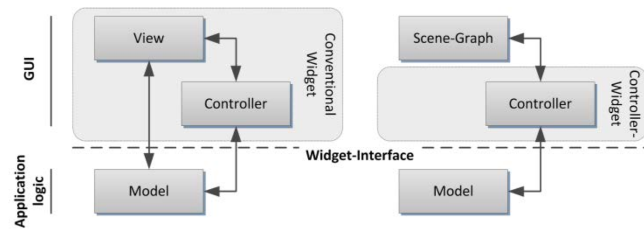

Figure 4 – Controller-Widgets vs. Conventional Widgets

The described approach enables the adoption of new design drafts with little effort. The static appearance of new GUI design can be evaluated in prototypes before the necessary widgets need to be available, since they are only required to add the dynamic behavior and to connect the GUI to the application logic.

5. IMPLEMENTATION IN MODERN 3D-HMI-DEVELOPMENT TOOLS

A new generation of HMI-development tools is needed to overcome the difficulties discussed above. Such development tools allow the direct reuse as well as the progressive refinement of design drafts and also the definition of static and dynamic behavior. Static behavior is created at design-time using animations while dynamic behavior is stimulated by events at run-time.

These tools are based on the concept of the model-view-controller pattern which masters complexity with its specialized roles in HMI development. Separation of different development aspects is also considered, such as ergonomic designs, run-time behavior, and cross-divisional tasks like configuration management, quality management and quality assurance. The complexity and specialty of each individual aspect leads to organizational and technical partitioning of the development process. The individual tasks are supported by separate tools which are integrated into an end-to-end toolchain. These tools can provide deeper expertise in this aspect compared to extensive multi-functional tools, since they focus on a single development aspect. Ideally, the highly specialized tools which form the toolchain can be selected independently from each other. This requires interface and workflow compatibility which is facilitated by supporting established industrial standards.

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[5] Model-View-Controller is a concept of the Smalltalk programming language [22] and is now often referred to as a design pattern. It separates the user interface into 3 parts with different roles. The *model* holds the state of the application and manages its data. The *view* renders a model into a form suitable for interaction with the user. The *controllers* mediate between both parts and control the user interaction [23].

5.1 Seamlessly Integrated Design Workflow

Professional modeling tools are used to create design drafts which are then imported into dedicated HMI-development tools using widespread standardized exchange formats. The data exchange formats in question are those supported by state-of-the-art design tools, e.g. image formats such as JPG, PNG, TGA, PSD, etc. and 3D design formats such as FBX and COLLADA. The data to be exchanged includes graphical artifacts (3D-models, textures, graphics), structural information about local or spatial relation between elements as well as chronological sequences in form of animations. 3D models also include special, non-visible elements like cameras and light sources.

After the design drafts have been imported they are available for usage and further adaption in the HMI development tools. These tools preserve and visualize all previously defined relations between the contained artifacts, such as the spatial relation of the scene-graph and animation sequences. The HMI development tool manages all imported design drafts in a library, thus containing elements that originate from different sources. These elements can be used to compose complex screen designs. This allows, for example, embedding a 3D vehicle-model coming from the CAD-department into design elements of a different source, such as a background image. This approach allows building consistent HMIs which are made of various graphical elements in a modular way. The individual modules can be of different complexity, ranging from atomic models or images up to complete screens and sceneries. The same modules can be reused for creating multiple views or scenes. They can also be used to create different design variants. By importing graphical design artifacts, animation sequences, and their relation redundant efforts can be omitted because neither elements nor their relations need to be specified in detail or created again.

Extensive rendering techniques like ray-tracing or radiosity are used in PC environments for 3D designs. On the one hand such rendering techniques provide realistic and sophisticated graphics. On the other hand though, they require computing power and architectures that are not available on embedded systems, while at the same time consume render time which does not allow real-time rendering. Rendering a single screen on a PC can take up to several minutes, depending on the complexity of the screen and effects. For 3D GUIs in vehicles, the same screen is required to be rendered in real-time, approximately 20 to 60 times a second, while maintaining a good appearance. For this reason, different rendering techniques are required to use 3D GUIs on embedded systems. This, in turn, can lead to a different appearance, which needs to be corrected by manual adjustments. Examples are inappropriate gap dimensions, aliasing effects, or different approaches for implementation of visual effects.

To overcome this discrepancy between traditional design and high render performance on target systems, HMI-development tools allow for adaptation and adjustment of graphical artifacts in different stages. While adaptation of 3D models is usually performed in 3D modeling tools, 3D HMI-development tools support adaptation depending on the rendering techniques and capabilities of the target system. Examples of the latter are the development of shader-programs for OpenGL-based rendering or the partitioning of a screen into multiple hardware layers. If necessary, the scene-graph can also be optimized with respect to light sources, camera settings, and model-relations. Furthermore, imported animations can be applied or enriched and new animations can be created.

These examples show that seamlessly integrated toolchains call for new activities and also affect the creation of the original design drafts. Furthermore, a new role needs to be introduced in the development process, a so called “Technical Artist”. Its task is to perform the optimizations for each particular target system. This requires knowledge of the capabilities of this environment and an understanding of visual design aspects at the same time. The role can be taken on by either an artist with technical skills or a software developer with graphical understanding.

Seamless model integration enables efficient development process for graphical design by omitting the need for extensive, detailed and potentially mistakable specifications. Iteration can be performed easier and faster since the barrier of media disruption and its related efforts is no longer present. It allows major adjustments and changes to the graphical design even in late development phases.

Seamless model integration also leads to an involvement of visual designers in the HMI development process on a technical level. This, however, poses new challenges. Up to now the concrete implementation of a design draft (e.g. polygon-count of 3D models or usage of light sources) had no impact to the final software for the target system due to process-separation per specification. This is not the case in seamlessly integrated development processes. Thus, the design drafts must take target specific specialties and requirements into account. This includes optimizing texture-sizes and 3D models with respect to rendering performance, placing light sources carefully, and implementing effects in a technology-aware way. Furthermore, the structure of the scene-graph needs to satisfy functional HMI requirements.

This leads to unusual requirements for design departments: They cannot chose an effect for the sole reason that it leads to the right graphical appearance. Instead of that, it has to be done with respect to the requirements and constraints of the final system. For instance, instead of using path-extrusion features of the modeling tool it may be necessary to model a fully extruded object which is reduced by shader-programs at run-time to achieve the same graphical appearance. Another example is the functional modeling of a vehicle miniature showing which doors are currently opened. For a proof-of-concept it is sufficient to only functionally model one door. However, the models required for creating the final HMI need to allow moving all doors in a physically accurate way. As mentioned before, such tasks are carried out by ”Technical Artists” who ideally perform them based on the original models of the design drafts. After that, the modified models are re-imported into the HMI-development tools. Because optimizations and adaptations are usually performed iteratively the HMI-development tools need to support updating already imported artifacts after they have been modified externally while preserving the adoptions performed in the HMI-development tool. Integration of behavior models and their loose coupling with graphical elements allows setting up a modular and flexible tool-supported process chain.

The HMI models need to be transformed into a format suitable for execution in the target system or a simulation of the target environment on a host system. HMI development tools need to make this task as easy as possible to enable rapid evaluation of design drafts in realistic settings. This in turn shortens the development time and provides higher flexibility with respect to design adaptations and prototype development.

5.2 Seamlessly Integrated Behavior Modeling

According to the model-view-controller pattern the specification and implementation of the HMI-behavior is the second major aspect of HMI development. For the most part, these behavior models can be developed independently from concrete graphical design. This section focuses on modeling dynamic run-time behavior while static behavior in the form of animations is considered to be created in the visual design workflow.

Various techniques are available for implementing the HMI-behavior. These include manual programming in suitable programming languages as well as automatic code generation based on visual notations such as state charts or mathematical models. Seamlessly integrated toolchains need to facilitate the transfer of the developed models to the target system. Besides technical constraints toolchains also need to consider the requirements of diverse developer roles with different skills.

Using UML-based state diagrams and transforming them into executable programs is a promising approach because it is relatively easy to learn and already widely known in software industry. Corresponding tools for behavior modeling that support this approach should ideally provide for both, graphical diagrams as well as textual representation of the state-machines. This is because depending on the task, both views can be beneficial. Such tools support graphical editing using UML or reduced UML dialects and textual representation based on domain specific languages (DSL). Compared to conventional programming languages, such DSLs possess a specialized vocabulary adapted to the needs of a specific domain. Due to the narrow focus they can provide a simple syntax and allow for compact specification. There are language workbenches for defining DSLs and creating a corresponding tool support including convenience features known from modern IDEs such as automatic syntax checks, auto-completion, command proposals, etc.. Such features reduce the amount of typing, help to avoid or even correct mistakes and therefore accelerate development. Furthermore, it is possible to validate the completeness, consistency and referential integrity of the models.

On the other hand, the graphical notation is beneficial for simple state-machines or high level descriptions. It is also reasonable to use a reduced level of detail that hides information which is not required to perform a specific task. This allows for a comprehensive presentation of relations and dependencies between the elements. Some tools also support the dynamic and interactive presentation of the model. However, with increasing complexity and level of detail the graphical notation becomes less beneficial, and textual representation has an advantage in such cases. Another way to cope with complexity in large scale behavior models is partitioning them, as some tools support. This enables a modular design, e.g. one state-machine controls the global HMI behavior while other state-machines control single screens in more detail.

Modern behavior-modeling tools support immediate simulation of the behavior model on a host environment and easy transfer of the model to the target system. To achieve this, different tools use different approaches, e.g. target-specific code generation or interpretation of the model at run-time. Seamlessly integrated toolchains need to support HMI evaluation in adequate environments as soon as the early stages. In later development phases they need to support developers to ensure controllability of the model and allow them to optimize it regarding memory consumption and performance. The complexity of the final HMI model is often underestimated in early development phases. Seamlessly integrated modeling calls for toolchains that allow successive development during all project phases as well as multiple iteration steps.

5.3 Integration of Design and Behavior: Controller-Widgets

Starting from a basic HMI concept, it is possible to develop graphical presentation and run-time behavior of the HMI in parallel. During the early stages, when no basic design drafts are available, simple visual elements, such as cubes or spheres, can be used to visualize the behavior model. Later on both development-strains are merged as part of the global development process.

Controller-Widgets are used to bridge the visual design and behavior elements and are thus available for modeling of both. They define fine-grained disjunctive functionality of only one or a few graphical elements. These graphical elements are manipulated by the Controller-Widgets' properties or controlled by animations. While most of these properties are set in the HMI development tool at design-time some of them are controlled by the behavior model at run-time. In contrast to conventional GUI-widgets, Controller-Widgets do not come with a particular visual presentation of the widget but use elements of the design model instead. Thus, the widgets' role with respect to the development aspects "Design" and "Behavior" is a different one (Figure 5):

- Their role in the design model is to map functionality provided by the behavior model to the corresponding graphical elements and animations. Note that modification to the design might break these connections. Thus, in the HMI-development tools the connections between controller widgets and graphical elements need to be modeled with certain flexibility. The connections set a search scope which is then used by the controller widget to find the actual required graphical elements. This approach allows modifying the structure of the design model without breaking existing connections. Of course, this does not apply any longer if the relevant graphical elements are removed or replaced.
- The purpose of the Controller-Widget in the behavior model is the same as that of conventional widgets: They provide an interface to control the graphical presentation.

The following example discusses opening and closing a door of a vehicle model. A possible implementation of a Controller-Widget offers a property to the behavior model which defines the state of the door – opened or closed. Another property of the widget is linked to an animation in the design model which defines the actual movement of the door. The widget starts this animation when the value of the property is changed at run-time. If this property is changed again before the animation ended the Controller-Widget can also adapt the animation. However, the actual basic animation is defined during graphical design process. Thus, it can be modified without changing the widget or the behavior model offering further degrees of freedom to visual designers. A different approach is required if the opening angle of the physical vehicle door shall correlate with the one of the doors of the 3D vehicle model. In this case, the widget needs to offer a property to the behavior model representing this angle with appropriate value limits. The behavior model propagates the opening angle of the real door to this property. The widget in turn modifies the opening angle of the graphical element accordingly.

The separation of concerns introduced by the Controller-Widgets offer some advantages compared to conventional widgets. As the previous example shows, a different behavior of the same graphical elements in the design model can be achieved by exchanging the widgets that control them. On the other hand the design can be modified without adapting widgets.

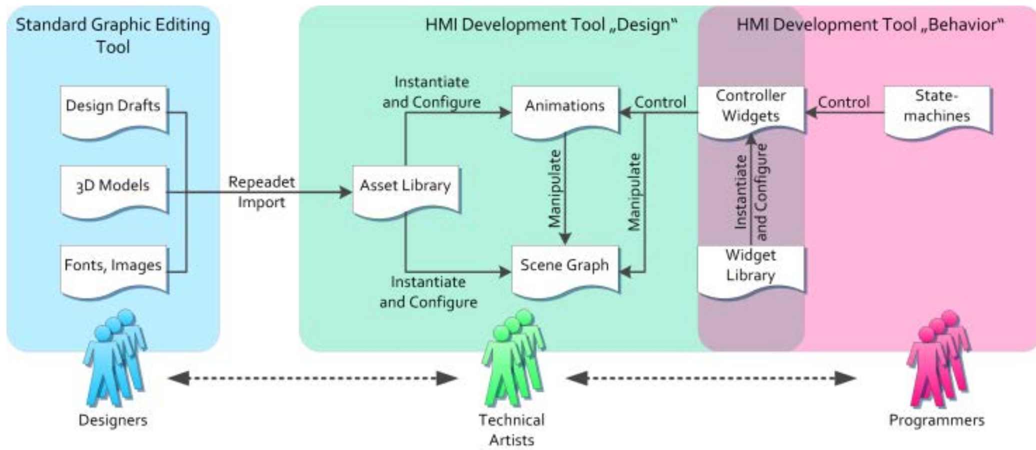

Figure 5 – Workflow and Roles using Controller Widgets

Libraries containing multiple Controller-Widgets can serve as a modular system. These libraries need to be offered in both, the tool used for graphical HMI-development as well as the one for behavior modeling. To integrate both of these into a single toolchain, they need to share information about types and instances of Controller-Widgets. This can be achieved by enabling the behavior modeling tool to query the available widget instances from the graphical HMI-development tool. The behavior modeling tool also needs to be notified when a set of widget instances was changed. It uses this information to make their properties available for data binding. That way, design and behavior are loosely coupled in terms of functionality and development workflow. Thus, Controller-Widget libraries enable seamlessly integrated toolchains for design, behavior and the integration of these major HMI development aspects.

6. EXAMPLE: CGI-STUDIO

CGI-Studio is a tool suite from Fujitsu Semiconductor Embedded Solutions Austria GmbH (FEAT) that enables the hardware-independent development of 2D, 3D, and hybrid 2D/3D HMIs based on Controller-Widgets. CGI-Studio focuses on graphical development aspects and currently consists of the following components:

- Scene Composer: a tool for authoring graphical HMIs
- CGI Player: a run-time environment for HMI application development, simulation, validation on host and target environments
- CGI Analyzer: a tool for design optimization regarding memory consumption and performance on target systems.

More tools are currently in development and there are plans for more as well, such as a tool for translating HMI into different languages. CGI-Studio contains the 2D and 3D rendering engine Candera that is designed for automotive target platforms based on OpenGL ES 2.0. Moreover, additional components are available such as the CGI Widget Library.

Graphical designs including 3D models, animations, textures, materials, fonts, images, and scene-graphs can be imported to CGI-Studio Scene Composer using FBX or other image and font formats. The imported assets can be used to model complex screens while adapting them for the rendering technology of the target. Scene Composer also supports importing and creating OpenGL shader programs and applying OpenGL ES 2.0 specific effects. Animations can be imported and modified or created from scratch. These animations can be assigned to multiple graphical elements. Iterative workflows are supported by enabling repeated imports of updated designs without losing previous modification to them performed in Scene Composer. By this means Scene Composer addresses the role “Technical Artist” by providing for its common tasks.

The widgets in CGI-Studio are based on the Controller-Widget concept. These widgets need to be programmed manually because on this level of detail the usage of compilable code has proven to be beneficial in the past. Of course, the widgets can also be implemented using different techniques, such as model driven development and code generation. Once a generic Controller-Widget library is available no coding is required to model the HMI.

CGI Player is an out-of-the-box HMI run-time environment that can be integrated into state of the art IDEs (e.g. Microsoft Visual Studio). The aim of this tool is to support the development of CGI-Studio widgets and the HMI application layer. During the widget development the CGI Player can be launched from the IDE which enables short edit-compile-debug cycles. The widgets are built on the API of the platform-independent Candera Graphic Engine. This engine is designed for the target system but is also used in CGI Player to simulate the HMI on a host environment. Hence there is no porting effort or a need for multiple implementations of the widgets. Instead, following the concept of a single source, the same widgets can be used for both purposes.

Because of tight development schedules the widgets and the graphical design are typically developed in parallel. That is why CGI-Studio supports the aforementioned mechanism to couple the Controller-Widgets to the graphical elements in a flexible way. The HMI models created in Scene Composer are exported as an “Asset-Library” which contains the scene graph and all its artifacts such as 3D models, animations, bitmaps, and fonts. It also contains the information about widget instances and their properties including their connection to graphical elements. CGI Player loads the Asset Library and renders the HMI using the Candera Engine. Because of the interpretative approach, no time-consuming compilation steps are necessary which allows for very short iteration-cycles.

CGI Player provides a customizable user interface to manipulate the widgets’ properties for testing purposes. The software of the HMI layer is the same with that which runs in the target system and the same APIs are available to control this HMI layer. The only difference is that in the target system the CGI Player’s user interface is replaced by the state machines of the behavior model.

Scene Composer also provides interfaces to query information about the available scenes and widgets to enable the integration with behavior modeling tools.

CGI-Studio is a tool suite based on the concept of controller widgets that allows building seamlessly integrated toolchains for 2D and 3D-GUIs development, analysis, and improvements in ergonomics- and concept-departments.

7. SUMMARY

The model-driven development of automotive HMI offers clear advantages compared to a manual implementation. However, it is crucial to have appropriate tool support available for creating and editing these models efficiently.

Present GUI modeling tools are based on widgets that come with a specific appearance which is manually programmed. This hinders a seamless integration of the tools that visual designers use to create GUI design draft and those applied to develop the models for generating the final HMI software. When it comes to 3D GUIs this approach is no longer possible.

Reducing the role of the widgets to a controller one enables to overcome this problem. Their appearance is defined by connecting these widgets to elements in a scene graph that was created using standard tools in graphic design domain. This approach is also applicable for creating widgets in 3D GUIs. Time-consuming reimplementation of design drafts is avoided reducing the efforts to adopt new GUI designs. This, in turn, raises flexibility in the HMI development and helps to achieve shortened development cycles.

8. ACKNOWLEDGEMENTS

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Skinning as a method for differentiating in-car infotainment systems

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ABSTRACT
In order to efficiently develop a software product family with products that are recognizable and distinguishable by the customer, one can modify the user-interface of a product's existing base-software (skinning). This paper introduces and defines the skinning technique and differentiates it from other practices. The required working steps as well as examples of supporting tools are presented. Possible uses of skinning for in-car infotainment systems are discussed. Finally, methods for applying skinning in different HMI-development methodologies are introduced and compared with one another.

Categories and Subject Descriptors
D.2.11 [**Software Engineering**]: Software Architectures – *domain-specific architectures, patterns;* D.2.13 [**Software Engineering**]: Reusable Software – *domain engineering;* D.2.11 [**Software Engineering**]: Miscellaneous – *reusable software;* J.7 [**Computer Applications**]: Computers in other systems – *consumer products.*

General Terms
Management, Design, Economics, Human Factors.

Keywords
HMI, infotainment system, automotive, product lines, skinning, branding.

1. BACKGROUND
Car passengers and drivers interact with the infotainment system of their car every day. Therefore, it is natural that they associate the look-and-feel of the system's user interface (HMI) with the vehicle's brand. As a consequence, the HMI needs to convey important customer values such as Corporate Identity and Corporate Design [9]. It also has to be in accordance with the car's interior design [11] and allow for differentiation from competitors [2].

Nowadays, the automotive industry is dominated by a number of companies that own multiple brands [9]. The cars they offer are built based on platforms that are used for multiple models and brands in order to reduce development and production costs. However, to make the cars distinguishable from each other the part that is visible to the customer has to be developed individually [10][1].

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This applies equally for the infotainment systems that are built based on shared platforms, too. In order to offer systems with brand- or model-specific HMIs, development has to be handled efficiently. The individual effort has to be minimized by reusing large portions of existing software and thereby avoiding multiple implementations - analogous to the approach taken for the overall vehicle. This includes changing the look-and-feel of existing software by applying appropriate modifications to the parts that are visible to the user, which is referred to as skinning.

When developing a set of software products, skinning is a useful technique to use for creating products with different look-and-feel. This is essential in order to attain a strong product differentiation and allow customers to perceive and relate to each individual member or its brand. This is necessary when multiple companies cooperate in the development of a system or share a common platform, and the final product is to be marketed using different brand names. It is also required when software system families are created by multi-brand companies that are common in the automotive industry.

A similar situation exists in the domain of mobile phones: companies want to have a consistent brand-specific look-and-feel for all of the products in their portfolio. However, these products may be built based on different supplier platforms (e.g., Android and Windows Mobile). At the same time, a single supplier platform can be used by multiple companies.

The following chapter explains how skinning can be used in the development of in-car infotainment systems. Later on, the paper discusses the working steps and technical solutions to apply skinning. Finally, an example of a tool supporting the skinning process is presented.

2. POSSIBLE APPLICATIONS
In the development of modern infotainment systems, the need for different ranges of functionality and individualized user-interfaces dictates that multiple software variants are to be created. Programming each of them from scratch is not reasonable. Instead, the software variants can be created using product line approaches [4] that allow minimizing the individual efforts. Such approaches build software based on reusable components, which only need to be developed once. Multi staged derivation processes can be applied in order to build large numbers of such software variants. An example of this is shown in Figure 1 and is explained below.

[1] The same strategy is also applied in other consumer products such as portable navigation devices, dishwashers or hi-fi systems, where the same internal hardware is used in products with different casing and user interface.

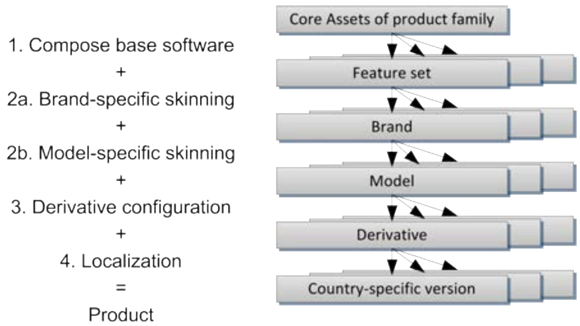

Figure 1: Example for the derivation process of a specific infotainment system variant

1. Infotainment systems come with a range of different feature sets. For example, one system may be available with or without navigation functionality. There are more optional features available such as CD-changer, iPod- or cell phone connector, telematics-module, etc. In order for each of these options to function, a particular software service as well as a user interface is needed in the infotainment system. Various software variants with different ranges of functionality are required that can be composed by taking components from the product-line-wide base of common assets (Core-Assets)[2] [4]. This process can be automated using certain tools. Variant-specific configurations are used to determine which core assets are to be combined and how they are tailored for each specific variant.

2. Infotainment systems with the same feature set are offered in different car models and brands. However, these features may need to be presented individually. In this case, skinning can be applied to modify the base software. Several of these skinning processes can be executed one after another (cascading skinning). This can be useful when skinning is applied for different purposes; such as a generic brand-specific design followed by a model-specific design (Figure 1). Splitting up the skinning in such a way reduces the complexity of each step. Furthermore, the intermediate results after the brand-specific skinning can be reused for the creation of the HMI of each of the brand's models. This can allow for abbreviating the derivation process when the software of multiple models of this brand is to be created at once [6].

   It is possible to present the infotainment system's base functions in different visual styles to the user, and allow him to choose those styles while operating the system. In infotainment systems to come the user might select different design profiles such as sport, eco or classic [12]. A simpler example that can be found today is the day- and the night-mode. The mode changes the display's colors and brightness, to avoid visual distraction and improve readability. Such a product feature can require having more than one skinned HMI in the same system.

3. Special edition vehicles or variants with different body shapes based on a single car model can use the same skinned base software. The necessary changes for each derivative require only minor adoptions to the HMI, which can be achieved by simple reconfigurations if they are adequately considered in advance.

4. Infotainment systems are built for cars that are marketed globally. In order to provide products that fit the customer's needs in each country, the infotainment system's software needs to be adapted. Besides technical adoptions in the base-platform this calls for culture-specific changes of the HMI. This includes the translation of all texts (in the GUI and the voice dialog system), the use of different units and date formats as well as the replacement of icons, images and colors [3,13].

   When localizing an HMI, the changes in the number and structure of the interaction components should be kept to a minimum in order to keep the variant diversity manageable. Hence, localization is providing country-specific content for the interaction components defined while skinning. However, some skinning-specific conditions have to be considered, e.g., the font and the available display space for the rendered text in the actual skin need to be known in order to avoid violating the bounds when translating GUI texts [6]. Therefore, each translation only has to be created for a specific skin and makes up an essential part of it (Figure 2).

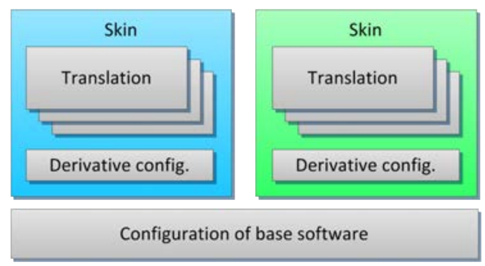

Figure 2: Configuration items required for the derivation of a specific variant with two different skins, and multiple translations for each skin

3. DELIMITATION

Contrary to the procedure described above for product line engineering (PLE), skinning uses the existing software of a specific product as a starting point and modifies the parts that are visible to the user (see Figure 3). Changing the base function available to the HMI goes beyond the scope of skinning. Thus, skinning can be seen as a special case of conventional PLE, which offers less variability and applies specific methods in the derivation process.

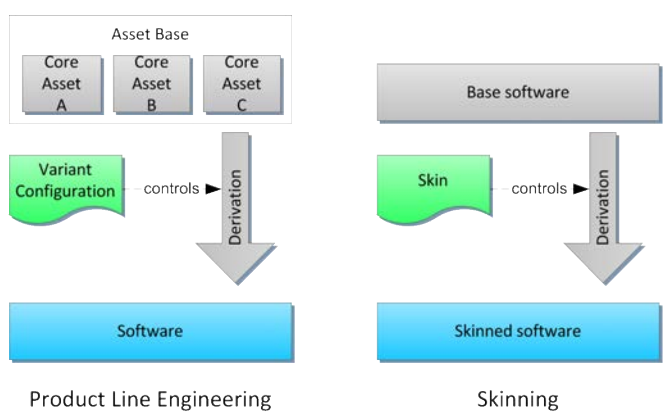

Figure 3: Comparison between PLE and Skinning

[2] The core assets alone do not form a product. A product is built by a combination of core assets and more elements.

4. STATE OF INDUSTRIAL PRACTICE

Specialized tools are used for developing HMIs in the automotive industry. In the context of a study, Volkswagen surveyed different tools that are available on the market which support the development of product families with individual HMIs. With few exceptions, most tools require to create all-new HMI-models for each HMI-variant. This approach allows for maximum degrees of freedom when designing each HMI, even though problems may arise when creating a large number of variants due to the duplication of identical parts. In one of the surveyed tools each color, font and image used in the HMI is given a name. Multiple profiles can be created that assign concrete values to each of these names. At runtime, the framework resolves a value with respect to the currently active profile. By selecting another profile the HMI's look can be adapted. In another tool this approach is extended: The HMI is built based on configurable interaction components (widgets). A default configuration has to be provided that assigns a base value to each configurable item. In order to create diverse designs, the HMI model can contain additional configurations that assign different values for a subset of all the configurable values. When such a configuration is applied, its values override the ones from the default configuration.

In HMIXML [10] the user interface design is stored in image resource files which are separated from the remaining models describing the HMI. These models and images are rendered in the final system. Skinning is done by exchanging the image files or the HMI-models.

Compared to HMIXML, WPF/Silverlight allows for more information to be taken out of the main XAML-model and put into separate resource files. These resource files can be exchanged to achieve an individual look-and-feel for each user interface.

A common technique used in web-design is that of style sheets. Style sheets describe rules that define how a website should be rendered. Applying another style makes the same website look different.

All these approaches are based on decoupling the elements to display from their presentation. This is done by introducing another level of indirection or storing them in different files, which allows for a simple separation of concerns between the different parties that are involved in the development of such a system[3]. However, none of the tools can be used in a skinning mode that prevents the developer from changing non-skinnable parts. Furthermore, when creating style sheets or manipulating resources it is hard to directly evaluate the impact on the modification in the HMI. As there is no specific tool to support this task, knowledge of programming and technical experience are required. This makes it harder for designers to accomplish.

5. THE PROCESS OF SKINNING

The paper has already presented the basic principle of skinning, its fields of application and its implementation in present tools. The following chapter describes the working steps that are required for employing skinning: the preparation of the base software, the creation of skins and their application on existing software.

[3] In the automotive industry the task of developing the basic HMI model, (interaction elements with no design definitions) could be assigned to one team that is working for all the brands of a development group, or to a specific leader-brand. Based on this basic HMI, each brand can create its own brand-specific designs.

5.1 Defining "skinnability"

It is wise to restrict the degrees of freedom before skinning. One may do so because of technical limitations of the selected implementation, or even for superior objectives and strategic considerations. An example could be to reduce the complexity or to assure an acceptable runtime performance of the system.

An exact definition of skinnable parts of the HMI helps enforce a structured process: When a modification needs to be made on the system for a single brand or product, this has to be approved by those responsible for the overall system. Such a structure can protect the parts of the HMI which are safety-critical or exceptionally important due to ergonomic criteria from unwanted changes.

5.2 Creating skins

In order to automate the skinning process all the relevant information needed to modify the base software are to be provided in a machine-readable way. The entirety of all this information is called skin[4]. It consists of configuration-information, software parts and resource files. All the files of a skin are often integrated into a single archive file in order to make it easier to handle.

The creation of such a skin should be supported by tools that allow modifications to be made only on those parts of the system that are marked as skinnable. Moreover, a preview of the skinned HMI should be available in the tool to provide a visual representation of the work in progress. An example of such a tool is the skin editor of the Video LAN Client (Figure 4).

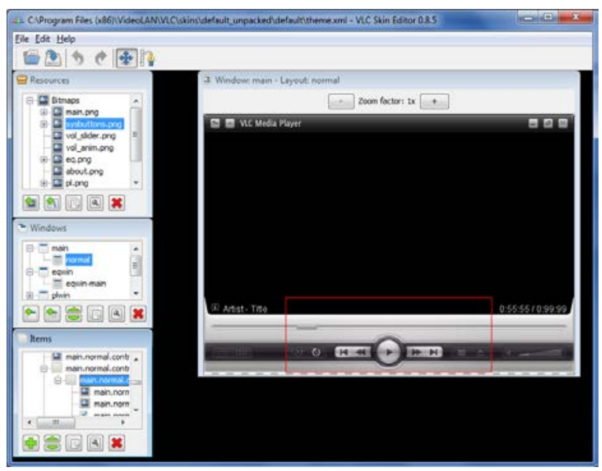

Figure 4: VLC Skin Editor

5.3 Applying skins

The most crucial step in skinning is to apply the skin to the base software. This needs to be automated, in particular if the base HMI and multiple skins are developed simultaneously. Applying the skin can be done at different points in time. Usually it is done at development time by the vendor. Alternatively, it can also be done after the base software has already been deployed on a

[4] In some cases a skin is also called theme or design.

system (runtime skinning) by either the (secondary-) vendor or the customer (personalization).

There are different ways to apply a skin depending on when it will be applied as well as who is the one who will be applying the skin. These are discussed below:

5.3.1 *Reconfiguring and changing resource files*

The simplest way to perform skinning is to exchange the resources of the existing software such as images, fonts and configuration files. In this approach the source code of the HMI is not changed (Figure 5). The skin is applied by copying the contained resource files to a designated location in the file system, possibly overwriting the previous ones. Such a process can be easily automated.

Figure 5: Reconfiguring and changing resource files

This approach is used by desktop-applications such as the Windows Media Player or the Winamp Player. It is also used by certain mobile phone manufacturers. This type of skinning can be done even after the deployment of the base software, because it does not require recompiling the software. Such skins have a simple structure and don’t require a lot of knowledge about the functional principles of the base software. Therefore, they can be created by customers, too.

However, this approach requires that all skinnable elements exist in the HMI already. They also have to be implemented in such a way that all skin-specific information is read from external resources. This can lead to additional implementation efforts in the base software. As reading and evaluating resources happens at runtime, performance drawbacks can be expected compared to a conventional implementation. Therefore, this approach is typically limited to images and fonts.

5.3.2 *HMIs interpreted at runtime*

Some frameworks interpret HMI-models at runtime [10]. In such a case, skinning can either modify the interpreted models or the interpreter. If the rules that control the interpretation are modifiable [1,8,5], skinning can also be done by adapting these rules (Figure 6).

Modifying the interpreter rules allows for a simple handling of skins since there is no need to maintain different interpreter software or modified versions of the large HMI-models.

Skinning by modifying the interpreter or its rules leads to a different rendering of the original HMI models. It also alters the rendering of all other compatible HMI-models. Therefore, it can be used to achieve a specific look-and-feel for HMI-models unknown at development time, e.g., HMIs of dynamic services [8]. However, this technique requires expert knowledge and therefore cannot be done by customers.

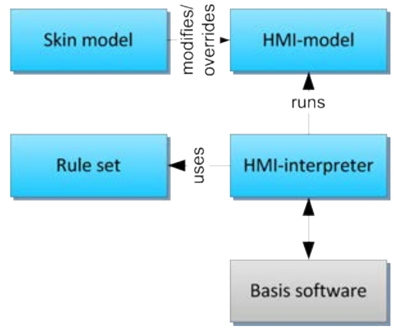

Figure 6: HMIs interpreted at runtime

In the case that a more specific adaptation is to be made, it is more reasonable to modify the interpreted HMI models directly instead of modifying the interpreter or its rules that affects the entire HMI. Initial models should not be changed since they are to be used in different vehicles, so skin-specific information can also be provided in a separate skin-model, which will override its counterparts from the HMI base model.

Maximum flexibility can be achieved when the interpreter, its rules, as well as the HMI-models are all adapted within the skinning process.

5.3.3 *Automatically generated HMIs*

Adapting the initial HMI-models or providing skin-specific information in additional models can also be done if they are not interpreted at runtime but are used to generate code. Just like modifying the interpreter or its rule set, such a code generator and its generation rules can also be adapted (Figure 7).

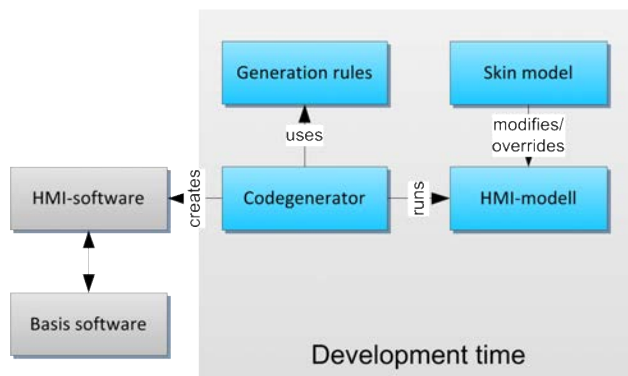

Figure 7: Automatically generated HMIs

Taking the skin-specific information into account during code generation, this approach reduces the number of decisions that have to be made at runtime. This allows for high runtime performance which in turn can reduce hardware costs. Such savings are especially significant when skinning is applied in order to use the same infotainment system for several brands and models. On the other hand extensive software has to be generated and compiled for each variant which leads to long turnaround times.

5.3.4 *Exchanging the HMI-software*

The previous chapter described how skinning can be implemented by modifying the code generator and the models it works on. As a result a different HMI-software is generated for each variant. The corresponding adaptations of the code can also be done manually if no model-driven development methods are applied

In order to keep the necessary effort as small as possible only software parts which are relevant for the look-and-feel are to be exchanged. This requires a sufficient decoupling, which can be achieved by the MVC-pattern or in a layered architecture, in which the HMI resides in the top-most layer.

Replacing the HMI-software with another manual implementation allows for maximum adaptability. However, it only makes sense in some cases since the synergy effect is low and the effort for creating each skin is very high.

A particularity arises if aspect-oriented programming (AOP) is used. AOP allows for separation of the skin-dependent part from the skin-independent part of the HMI's source code without dictating specific software architecture. Both parts are then assembled using weaving during compilation or runtime[5]. This additional step leads, though, to more complexity (Figure 8).

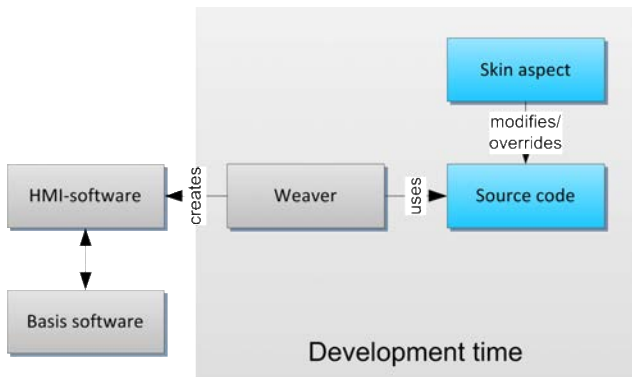

Figure 8: Exchanging the HMI-software

6. EXAMPLE AND USAGE SCENARIO

The Volkswagen Group applies skinning in the development of its infotainment system families, which are used by many brands and in many models. The hardware and basic services are standard across the brands. Based on that, a basic Volkswagen HMI is developed using model driven approaches and code generation. In order to offer products with their own brand-specific design the individual company brands adjust this basic HMI by skinning. They use skin editors to create the skins that are applied by automatically adapting the base HMI-models before code generation.

7. CONCLUSION

In the development of infotainment systems skinning can be applied for different reasons. The skinning techniques available were discussed in this paper. Which one is suited for a particular purpose primarily depends on who is to use them and at what point in the development process. Table 1 below summarizes these results. Note that some of the skinning techniques can also be used together.

The HMI implementation should be carefully planned when developing a system that employs skinning, so that the development methodology is defined with respect to the different skinning techniques that exist.

[5] Runtime weaving requires the usage of additional libraries and can lead to performance drawbacks.

8. ACKNOWLEDGEMENTS

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Table 1: Comparison of different skinning techniques (+ good, ○ average, - worse)

Skinning technique	Effort	Applicability for customers	Turnaround time	Runtime performance	Adaptability	Scalability	Recommended application
Reconfigure or exchange resource files	+	+	+	-	-	○	Personalization by customer
Modify interpreted model or provide skin model	○	○	+	○	+	+	Localized adaption by OEM
Modify interpreter or its rule set	○	○	○	○	+	-	Global adoptions by OEM and adoptions of HMI-parts unknown at development time
Modify model for code generation or provide skin model	○	-	-	+	+	-	Localized adoptions by OEM with high runtime performance
Modify code generator or generation rules	○	-	-	+	+	+	Global adoptions by OEM with high runtime performance
Replace HMI-layer or aspect	-	-	-	+	+	+	In exceptional cases only, e.g., fundamentally changed control concept

Third International Conference on Automotive User Interfaces and Interactive Vehicular Applications

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ABSTRACT

Following laws and provisions passed on the national and international level, the most relevant goal of future vehicular interfaces is to increase road safety. To alleviate the cognitive load associated with the interaction with the variety of emerging information and assistance systems in the car (and to increase driving performance as well), subliminal persuasion is assumed to be a promising technique to reduce the amount of information the driver must store and recall. Subliminal cues could be provided across appropriate sensory modalities, according to the specific nature of the current task, and corresponding to drivers' cognitive abilities.

The central objective of this workshop is to provoke a lively debate on the adequacy of information provided below active awareness and to discuss how to resolve potential problems in this highly risky research field. This approach exhibits exciting challenges, which can – once fully understood – impact on society at large, making significant contributions toward a more natural, convenient, and even relaxing future style of driving. Therefore, and to further strengthen significance of results, the workshop is directed at researchers from a range of disciplines, such as engineering, neuroscience, computer science, and psychophysiology.

1. COGNITIVE LOAD AND DRIVING

The application of subliminal techniques to improve driver-vehicle interaction is a timely, relevant topic to be discussed, underpinned by the facts that cognitive abilities of the driver as well as its attention are limited resources [4], and even more as vehicle operation requires an ever increasing level of attention. Reasons include (i) the emergence of new driver information and assistance systems, (ii) more and more cars on the road, (iii) rising number of traffic signs, and (iv) penetration of car-to-car communication. This divergence demands for new ways and means of communication to prevent information overload and a stipulated, overburdened cognitive channel in future. This request is even more tightening as novel, recently emerged interfaces employing multimodality or using implicit interaction also hit their limits. This is supported by studies having verified that vehicle accidents today are more than 90% caused by driver error [5]. The accidents reported does not only have its origin in driving errors such as tailgating, suddenly changing lanes, or overestimating driving skills [6, p. 59f.], but also have its seeds in cognitive overload, e. g., when task difficulty exceed resources available by the driver or from reduced situation awareness in times driving at high workload levels. For cognitive overload it has been proven that the driving performance declines, finally resulting in higher safety risks [4]. Unfortunately, major difficulties in its detection (and avoidance) are the facts that (i) the capacity available by a driver is not constant while driving [2] and (ii) that it is almost impossible to determine the exact point where cognitive overload starts to occur. Reasons for the latter issue are that the driver tends to alter his/her task management, e. g., by decreasing the speed when engaged in side activities [10, p. 338], or by excluding or omitting certain elements.

This short review makes it clear that approaches involving drivers' cognitive resources are needed to ensure safe vehicle operation in future. In case of supported functionality, subliminal persuasion carries great potential to reduce cognitive load, stress or incorrect decisions. This assumption is based on the result of cognitive and social psychologists, who have learnt that stimuli presented subliminally can have a considerable influence over a variety of cognitive processes, possibly even behavior. The main idea is to “inject” information into a driver's mind below active awareness, thus transferring supplementary information in a subliminal style without adding load on the cognitive channel. The main benefit of this approach would be the reception of additional, essential information even in the case where almost no capacity is left for information transmission in a traditional way. It is anticipated that, for example events of sudden danger, could be avoided using this technique.

Potential of Subliminal Perception

The notion that stimuli presented below conscious awareness could influence cognition is not new – Peirce and Jastrow [7] were the first reported in 1884 that people could perceive small differences in pressure to the skin without conscious awareness of different sensations. Moreover, it is well known that certain subliminal cues can facilitate certain behaviors. For example, store chains sprays fragrances with a subtle influence outside their stores to attract customers, background music in shopping malls is said to increase sales by subliminally stimulating shoppers, and millions of people buy subliminal audiotapes to help them lose weight or increase their assertiveness.

Quite recently, there have been some attempts made to extend current user interfaces by means of subliminal com-

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munication, with examples being adaptive user interfaces, subliminal teaching techniques, or neurofeedback systems to enhance well-being. Subliminal techniques have also been used in driver state analysis systems or in road layout optimization based on driver behavior [9]. We propose to employ subliminal techniques as an encouraging approach to provide the driver with (noncritical) driving related information without dissipating available attention resources.

2. OBJECTIVES OF THE WORKSHOP

In this workshop, we will pick up on all the previously discussed ideas and put them into an automotive context. The central objective of this workshop is to **provoke a lively debate on the adequacy of information provided below active awareness and to discuss how to resolve potential problems** in this highly risky research field.

This discussion is long overdue, confirmed e. g. by [8, p. 339] who noted that "*researchers have failed to produce reliable subliminal effects for at least three reasons*": (i) inconsistent use of the term " subliminal", (ii) lack of adequately precise, standardized methods, and (iii) lack of an adequate conception of subliminal processes. And in addition "*[..] as a consequence of these problems, it has not yet been possible to describe, with confidence, conditions under which subliminal effects are likely to occur*".

Subliminal information processing raises elementary questions including

- "How good is the mind at extracting meaning from stimuli of which one is not consciously aware?" [3],
- "How to measure the positive effect of subliminal information cues?", or
- "How something presented subliminally would persuade a driver if he/she did not consciously attend to it?" (as it is generally accepted that such stimuli are weak and often presented at very low intensity [1]).

To answer these questions we would like to invite researchers to take part in an in-depth, interdisciplinary discussion of this timely, relevant, and important field of investigation.

We assume that a broader knowledge of subliminal perception and persuasion would have much potential in improving driver-vehicle interaction. It has to be pointed out once more that this is high risk research and it cannot be taken for granted at all that answers can be found to the stated research questions. The fact that subliminal information poses high danger for driver, passengers, and other road participants (if used in real traffic and for driving related information) has to be emphasized when defining/conducting experiments in the wild. But on the other side, as nonhazardous information does not require active attention of the driver and hopefully does not compromise safety risk, this kind of information could be transmitted subliminally.

Topics of Interest

The workshop will address the following issues:

- Taxonomy of the terms: implicit, subliminal, supraliminal, priming, conscious, preconscious.
- Philosophy or rationale for the use of subliminal interfaces.
- How to reduce "risk" in subliminal interfaces?
- Socio technical issues, e. g., social acceptance and/or aversion/repulsion about this type of technology?
- Is the perceived information difficult to interpret?
- Is there an influence on individual differences such as age, gender, intelligence, characteristics, abilities and disabilities, cognitive style, cultural differences, etc.?
- Evaluation techniques for the perception of subliminal information
- Is an impact of subliminally delivered information discoverable on the cognitive load or perceived workload (e. g., using NASA TLX)?
- What are appropriate subliminal techniques for workload reduction while driving?
- Subliminal interfaces for the automotive domain (head-up displays, vibro-tactile transducers, olfactory stimulation, brain-computer interfaces (BCI))
- What are characteristics of subliminally delivered information (e. g., reachable bandwidth, natural bounds, complexity of information, speed of perception, appropriate modalities, strength/duration/frequency)?
- Potential of subliminal cues to guide a driver to the right course of action or to a specific emotional state?

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Message from the Workshop Organizers

Introduction

The aim of this workshop is to discuss the potential and possible application of subliminal techniques employed to counteract the problem of limited cognitive abilities and bounded attention of a driver. To alleviate the cognitive load associated with the interaction with the variety of emerging IVIS/ADAS in addition to the driving task, we assume that subliminal techniques offer high potential to significantly reduce the amount of information to be processed simultaneously. These cues should be provided using appropriate modalities (visual, auditory, tactile/haptic, olfactory, etc.), following the specific nature of the task to fulfill, and according to a driver's abilities.

As research and discussion on subliminal techniques would benefit from a significant collaborative effort from a range of disciplines like engineering, neuroscience, computer science, psychophysiology, we have invited researchers from these fields to submit their position paper. We are sure that the approach provides exciting challenges, which will significantly impact on society at large, making significant contributions toward a more natural, convenient, and even a relaxing future style of driving.

Summary of Contributions

The position papers submitted to the workshop of "Subliminal Perception in Cars" have undergone a rigorous peer-review process where the manuscripts were reviewed by two to three reviewers each. In the end, 6 position papers were selected for the publication in the workshop proceedings and presentation/discussion at the workshop, held November 30th, 2011 in the frame of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications.

The first paper by Peter Sinclair presents a very interesting concept, Road Music, for a dynamic music generator conditioned by the driving style and road environment. The approach differs from commercial products in that it does not make use of audio tracks that are selected according to driving parameters, but instead alters the melody parameters such as pitch, tempo and tone based on multitude parameters. This will probably spark quite a few interesting discussions/debates over the subliminal perception of automated, real-time, generated music.

The next paper by Jeon and Walker provides a good review of how to design unobtrusive affect detection and mitigation systems in the area of in-car interaction from a cognitive/psychological point of view (concluding most profound ways are speech and facial detection). This paper would "drive" further discussion at the workshop with the subject matter.

The position paper by Angela Mahr focuses on research exploring the possibilities of the use of speech and sped-up speech for in-vehicle contexts. The paper is suitable for the workshop because it treats with one of the natural and unobtrusive communication ways, namely "speech". Moreover, sped-up or compressed speech is one of the well-known subliminal process examples in psychology. The "Semanticons" approach of the author seems to be a plausible way and worth investigating further and the authors' previous work using a robust cognitive psychology experimental paradigm has been nicely wrapped-up to proceed with discussion in the workshop.

The fourth paper by Andreas Riener gives an interesting presentation of possible subliminal techniques and their application in the car, enriched with critical assessment of consequences of affect on driving. Interesting is the reference of the two possibilities for displaying the drivers affect. Visible, for example on an emotion-gauge, or in a more unobtrusive way by an adaptively display. In particular, the details given about information processing and the capabilities of the diverse sensory channels could add a interesting view on the discussion at the workshop.

The next paper by Joseph Fellner describes the core research interests of AUDIO MOBIL, an internationally acting automotive system supplier and system service provider, in the field. The company focuses on HME (human-machine-environment), HMI (human-machine-interaction), vehicle-to-X-communication, driver assistance systems and car infotainment. With regard to the workshop, AUDIO MOBIL is mainly interested in the field of infotainment and entertainment for a driver and passengers. Including the "view" of the industry, not only its wishes and recommendations, but also criticism and concerns would direct the discussion at the workshop to a "more realistic" and goal driven route.

The last paper presents a driving simulator experiment with different visual stimuli related to vehicle speed. This research corresponds to the workshop in that it provides an unobtrusive cue in the peripheral visual area. When it comes to subliminal perception, people are likely to think about non-visual modalities, such as auditory or tactile displays. However, the provision of the information in peripheral vision might be an alternative method instead of that in the focal vision area. This research is expected to enrich the workshop discussion in terms of adding a typical (but not usually considered in a subliminal perception domain) modality.

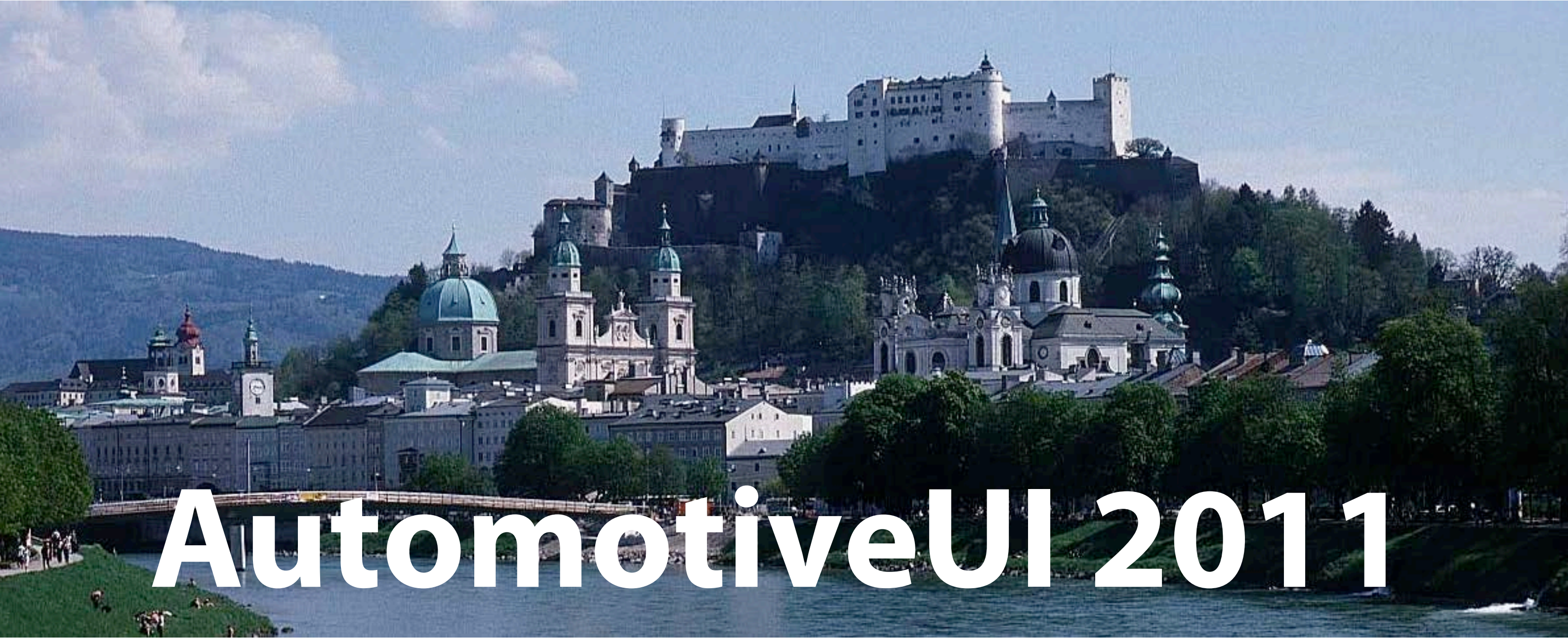
Conclusion

The authors of this workshop have shown very diverse approaches of how to implement or apply subliminal persuasion and perception in driver-vehicle interaction. We believe that this cross-section of research projects and industry interests in the broader field of subliminal perception in cars illustrates the potential application of subliminal techniques holds to improve driver-vehicle interaction or driving experience. Nevertheless, it also highlights that there are still technical difficulties and unresolved problems limiting a broader deployment in the near future.

As a concluding remark, we would like to thank all the authors and reviewers for their excellent work.

Andreas Riener
Myounghoon Jeon
Joseph Fellner
Manfred Tscheligi

For up to date workshop information please visit http://www.pervasive.jku.at/AutoUI_subliminal



Third International Conference on Automotive User Interfaces and Interactive Vehicular Applications

November 29—December 2, 2011
ICT&S Center, University of Salzburg
Salzburg, Austria

Adjunct Proceedings
Workshop "Cognitive Load and In-Vehicle Human-Machine Interaction"

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The effects of visual-manual tasks on driving performance using a military vehicle on a dirt road

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ABSTRACT
Driver distraction is deadly. In the United States alone, approximately 25 percent of all automobile accidents and 21 percent of all fatal accidents occur as a result of driver distraction in civilian settings.[1] However, it is more difficult to estimate the impact of driver distraction on military personnel. One similarity between civilian and military operating environments is the increasing proliferation of in-vehicle information systems. The purpose of this study was to examine the effects of three different visual-manual secondary tasks on participants' driving performance. All tasks required participants to interact with touch screen technology. The results indicated that participants' performance was significantly impaired during conditions when they executed a secondary task.

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

General Terms
Measurement, Performance, Experiments, Human Factors

Keywords
Distraction, driving, touch screen technology, military

1. INTRODUCTION
Traffic related fatalities are one of the leading causes of death in both civilian and military settings. In the United States, 32,261 civilians died and another 2.3 million were injured in motor vehicle accidents in 2008. Among military personnel, motor vehicle crashes are the leading cause of death and are ranked in the top five leading causes of hospitalization among warfighters.[7]

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In fact, the United States Army reported that approximately 40 percent of the total number of noncombat deaths was caused by combat vehicle or motor vehicle accidents since the beginning of the War In Iraq in 2003.[10] Indeed, root cause analyses of these accidents indicated that their leading cause was "human error".

In the driving domain, human error may result from a variety of factors which include but are not limited to failures in perception or comprehension of environmental cues and the failure to project those environmental cues into the near future.[3] One precursor of the aforementioned factors is distraction. In fact, distracted driving accounts for an estimated 25 percent of all automobile accidents and 21 percent of all motor vehicle fatalities in the United States.[1]

Moreover, numerous experimental and epidemiological studies indicate that distractions negatively affect drivers' performance in civilian settings.[2,14] However, it is more difficult to estimate the impact of driver distraction in military settings for several reasons: Firstly, military motor vehicle crash rates are not widely published. Of the studies that examine crash rates, few distinguish crashes that involve personally owned vehicles (POV) from those that involve military motor vehicles (MMV). This means that frequently, reported crash rates are based on a combination of the two types of vehicles, and thus, may have very different characteristics. Similarly, the causes of military accidents are not widely published. Although "human error" has been cited as a contributing factor, the nature and impact of this factor on military crash statistics is relatively unknown.[4]

Military operational driving environments differ from civilian driving environments. Military drivers operate under risky conditions, in both on and off-road contexts, in convoys, and in combat settings while wearing heavy gear, which may limit drivers' physical mobility, hearing, and vision.[7] Thus, performance measures and interventions suitable for drivers operating POVs in civilian settings may not be applicable to drivers operating military owned vehicles in combat settings.

In addition, laboratory studies that simulate military environments may not capture essential characteristics of both MMVs and their operating environments. Thus, performance observations resulting from a simulated environment may not translate to the actual operational context, thereby affecting external validity.

Although differences between civilian and military driving environments exist, their in-vehicle context does share one similarity: in-vehicle informational systems (IVIS). These include but are not limited to global positioning systems (GPS), music applications, wireless communications technology, gaming systems, and even televisions. Albeit highly unlikely that military drivers would interact with gaming or music systems during combat situations, they often interact with particular IVIS systems including those that relate to command and control operations and GPS. Thus, the potential for driver distraction does exist within this context.

1.1 Types of Distractions

Although distraction has not been extensively studied in MMVs, some tenets of previous studies conducted in civilian settings may be extended to these environments. According to the National Highway Traffic Safety Administration (NHTSA), there are three main types of distracted driving: visual, manual, and cognitive. Visual distractions occur when drivers avert their eyes from the driving scene. This may occur when drivers dial a number on their cell phone. Manual distractions occur when drivers remove their hands from the wheel. Examples of manual distractions are eating, grooming, or changing the radio station. Cognitive distractions occur when drivers' attention is shifted from the driving task to the contents of their mind. These distractions occur even when drivers' eyes are directed at the roadway and even when their hands are located on the steering wheel.[8,12] Examples of cognitive distractions include cell phone conversations, thinking about tasks or goals, and daydreaming.

There have been several attempts to rate the level of distraction that each task poses. Nakayama, Futami, Nakamura, and Boer (1999) parsed distractions into the categories of conversations, thinking, eye diversions, and the operation of equipment and reported that drivers' distraction increased in that order.[11] Research conducted by the National Highway Traffic Safety Administration was congruent with this categorization.

1.2 Purpose

It is well documented that distracted driving is a major contributor to vehicle accidents in civilian setting. Past research performed in driving simulators has shown that distraction impacts a number of performance measures including reaction time, steering entropy, acceleration, brake reaction time, lane maintenance, speed, heading, and crash rate.[5] However, as mentioned previously, the impact of distracted driving in military environments is relatively unknown. Thus, one purpose of the current research is to extend the prior research on distracted driving to an environment that shares some salient features with military environments.

During the current study, participants drove a Humvee equipped with performance measurement equipment on a closed, off-roading test course. All participants completed the test course 1) without performing a secondary task (i.e., during an attentive driving condition) and 2) while performing three different visual-manual secondary tasks using touch screen technology (i.e., during distracted driving conditions). We predicted that participants' performance would suffer more in the distracted driving condition compared to the attentive driving condition.

2. METHOD

2.1 Participants

Sixty-seven male and female employees from Sandia National Laboratories in Albuquerque, NM, ages 22-50, participated in this experiment. All drivers reported possessing a current driver's license and normal or corrected to normal vision.

Apparatus and Materials

2.1.1 HMMWV

The Army Research Laboratory Human Research and Effectiveness Directorate provided an instrumented military HMMWV for this research. The vehicle was an automatic and provided a range of inherent sensors that collected driving performance data.

2.1.2 Cameras

There were four cameras that recorded various driving views from within the vehicle. Two of these were forward looking, giving a view of the road in front and to the side of the driver. Another camera recorded the driver's face and additional camera recorded the controls over the driver's right shoulder. All camera views were combined into a composite video stream.

2.1.3 Laptop

The software ran on a ruggedized laptop with a solid state drive running the Vista operating system. It was connected via Ethernet to the data acquisition equipment where it periodically (4Hz) received a data packet with sensor data in it. In addition, the laptop interfaced to an I/O box to present the subject with experimental tasks and record their behavioral responses (i.e. button presses). At the end of each trial, the video files and data files were downloaded from the vehicle.

2.1.4 Experimental Setting

Experimental testing was conducted on unimproved dirt roads near the Robotic Vehicle Range at Sandia National Laboratories. The course consisted of three roads and was approximately 6.6 miles long. The speed limit on the course was 20 mph.

2.1.5 Simulated Braking Task

Throughout all experimental trials, participants responded to an LED light that was mounted in the front window of the vehicle by pressing a button that was located on their right index finger. This light turned on and off randomly throughout the experiment. This task was meant to simulate the braking of a lead vehicle.

2.1.6 Experimental Tasks

2.1.6.1 Short-glance Task

During the short-glance task, participants monitored a series of circles on a touch screen. Participants' task was to indicate which circle was highlighted immediately before all circles turned red. Participants accomplished this by touching the last-highlighted circle on the touch screen. This task required the driver to share visual attention between the road and the task, glancing back and forth for short periods. The overall distraction (involving approximately 10 responses) lasted approximately one minute per block. There were 13 blocks during the 30-minute experimental driving loop. See Figure 1 for an illustration of this task.

2.1.6.2 Long-glance Task

As shown in Figure 1, the long-glance task used the same dot row previously discussed, with the exception that 4 dots were randomly presented for 500ms. This task required participants to remember the sequence of dot presentations, and when prompted, to touch the circles in that sequence in order to score a correct answer. This task required a longer glance than the short-glance task.

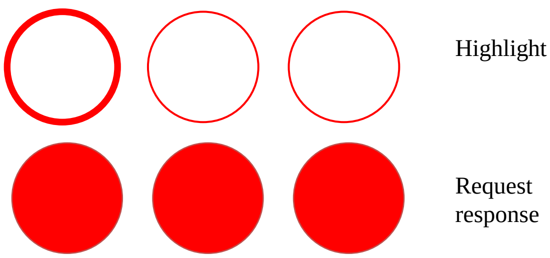

Figure 1: Dots for Short and Long Glance Tasks

2.1.6.3 Table Task

During the table task, a six-column table was presented with alternating letter and number columns. The letters were associated with radio call signs (e.g. A=alpha, B=beta, etc.). An auditory cue was given with the call sign as the table was displayed. The task was to search each letter column for the call sign letter and to identify the digit to the right of it. Participants entered the three digit code on a touch screen keypad. After entering the first digit, the table disappeared, requiring the driver to memorize the 3-digit sequence before entering their response. The assignment of digits to letters and the order of letter and number presentations in the table were randomly generated for each presentation. See Figure 2 for an illustration of this task.

A	**1**	**B**	**1**	**E**	**1**
T	**3**	**T**	**2**	**Z**	**3**
C	**6**	**Z**	**6**	**B**	**6**
D	**4**	**D**	**5**	**F**	**4**
B	**9**	**A**	**9**	**C**	**9**
E	**2**	**F**	**4**	**A**	**2**
F	**8**	**E**	**3**	**D**	**8**
Z	**5**	**C**	**7**	**T**	**5**

Figure 2. Table Task

2.2 Experimental Design

There was one independent variable in this experiment: driving condition. This variable had four levels: All participants drove the test course 1) without performing a distracting secondary task, 2) while performing the short glance task, 3) while performing the long-glance task, and 4) while performing the table task. The former condition served as a baseline performance measure and the latter three served as treatment conditions. The resulting design was completely within-subjects.

Several dependent measures were collected. Firstly, participants' reaction time and accuracy on the distraction task and the simulated braking task were collected. Reaction time was measured from the beginning of each task. Accuracy was defined as the percentage of correct trials.

Additionally, participants' performance on the following driving measures was collected: average speed, average number of steering reversals, and average number of throttle reversals. All of the aforementioned measures were sampled at a rate of 250ms and averaged across trials. Speed was measured in mph. Steering reversals were defined as the average number of deflections away from a neutral steering position followed by a reversal of the steering wheel back to the neutral position that were executed within one second.[9] Similarly, throttle reversals were defined as the average number of deflections of the throttle away from a neutral point followed by a reversal of the throttle back to a neutral position that were executed within one second.[8]

2.3 Procedure

Before the experiment began, participants practiced the three different distraction tasks in the stationary vehicle. Afterwards, they were instructed to maintain a 20mph speed limit and drove approximately one quarter of the course in order to gain familiarity with the vehicle. Then, they practiced each of the distraction tasks sequentially while driving.

After practice, participants were informed that their primary task was to drive the vehicle safely and to complete any additional tasks only when they felt that the driving conditions were safe enough to do so. Participants executed four different driving conditions: 1) a baseline condition, in which participants drove without completing a distraction task, 2) a condition in which participants completed the short-glance task, 3) a condition in which participants completed the long-glance task, and 4) a condition in which participants completed the table task. The order of these conditions was counterbalanced across participants. With the exception of the practice period, participants completed only one type of distraction task type within a driving condition. The experiment took approximately 3.5 hours to complete.

3. Results

All dependent measures were inspected for outliers using the z score method.[6] Items receiving a score of $\pm$ 3 were replaced with the next highest or lowest score that was not considered an outlier for that particular condition. Only 2.3 percent of the data were replaced. By using this particular method, variance was not unnecessarily reduced.[14]

3.1 Did participants perform as instructed?

Single sample t-tests were conducted to determine whether accuracy on the secondary distracting tasks was significantly different from chance. This was done in order to determine whether participants were performing the task as instructed or whether they were simply guessing (i.e., attaining a 50 percent performance rate). As shown in Table 1, single-sample t-tests revealed that participants performed significantly better than chance on all three secondary tasks. This means that participants were indeed performing the tasks as instructed.

Table 1. Percentage accuracy compared to chance on secondary tasks

Task	Mean	SE	Result
Short-glance	94.10	0.42	$t(66) = 107.83$, $p < .001$
Long-glance	84.59	1.08	$t(66) = 31.89$, $p < .001$
Table	96.26	.40	$t(66) = 116$, $p < .001$

3.2 Were participants significantly distracted?

A one-way ANOVA was conducted in order to determine if participants' response times to the simulated brake light were significantly different during the attentive driving condition compared to each distracted driving condition. The results indicated that participants responded significantly faster to the simulated brake light during the attentive driving condition compared to the distracted driving conditions $F(3, 64) = 62.32$, $p < .001$. As shown in Figure 1, Tukey's comparison tests revealed significant differences between attentive driving and each condition, respectively. Thus, participants were significantly distracted when they performed a concurrent secondary task while driving.

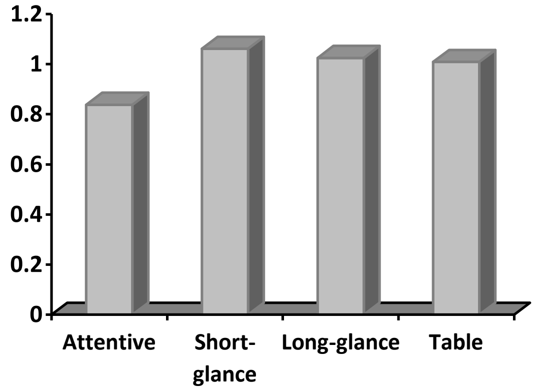

Figure 1. Response times to simulated braking light

3.3 Did the secondary tasks impair driving performance?

Dependent samples t-tests were conducted in order to determine if there were significant differences in performance between distracted and attentive driving conditions for all dependent measures. In order to effectively compare experimental and baseline conditions, the segments from the baseline condition were matched to the exact points along the driving course where the distracted driving tasks occurred for each participant. This was done because distraction tasks occurred along different parts of the route for each participant. Then, all of these points were averaged for each condition. This allowed a direct comparison of participants' driving performance while controlling for the effects of test course difficulty at different points along the route. Thus, each dependent measure has three baseline performance values that correspond to each of the three secondary tasks. All results are significant at $p < .05$.

3.3.1 Average Speed

As shown in Table 2, dependent sample t-tests indicated that participants drove significantly slower during all three of the secondary task conditions compared to the attentive driving condition.

Table 2. Significant differences in average speed between secondary tasks and matched baseline conditions

Secondary Task	Secondary Task		Matched Baseline		Result
	M	SE	M	SE	
Short glance	21.77	.07	22.29	.07	$t(66) = -10.65$, $p < .001$*
Long glance	21.89	.05	22.19	.05	$t(66) = -7.74$, $p < .001$*
Table	21.88	.05	22.08	.05	$t(66) = -5.30$, $p < .001$*

3.3.2 Steering Reversal Frequency

As shown in Table 3, participants had significantly more steering reversals when performing each secondary task compared to a matched baseline condition.

Table 3. Significant differences in steering reversal frequency between secondary tasks and matched baseline conditions

Secondary Task	Secondary Task		Matched Baseline		Result
	M	SE	M	SE	
Short glance	52.19	.57	39.67	.54	$t(66) = 26.92$, $p < .001$*
Long glance	3.87	.05	3.01	.05	$t(66) = 16.85$, $p < .001$*
Table	6.40	.07	4.96	.07	$t(66) = 21.99$, $p < .001$*

3.3.3 Throttle Reversal Frequency

Table 4 shows significant differences in throttle reversal frequency between the short glance and table tasks compared to their matched baseline conditions. The results indicated that participants had significantly more throttle reversals during distracted driving conditions compared to an attentive driving condition. There was no significant difference in throttle reversal frequency between the long-glance task and its matched baseline condition.

Table 4. Significant differences in throttle reversal frequency between secondary tasks and matched baseline conditions

Secondary Task	Secondary Task		Matched Baseline		Result
	M	SE	M	SE	
Short glance	29.72	1.33	23.61	1.08	$t(66) = 4.60$, $p < .001$*
Long glance	1.73	.06	1.77	.06	$t(66) = -.49$, $p > .05$
Table	3.53	.11	2.89	.09	$t(66) = 5.74$, $p < .001$*

4. DISCUSSION

Our results indicated that participants' accuracy on each secondary distraction task was significantly higher than chance. This means that participants were performing the tasks as instructed and that they were not simply guessing. Moreover, participants' accuracy was very high. This may mean that these tasks may have posed a relatively light cognitive load.

Additionally, participants responded significantly more slowly to the simulated brake light during the distracted driving conditions compared to the attentive driving condition. This means that participants' cognitive load was higher during the distracted driving conditions than during the attentive driving condition and that they did not have enough mental resources to execute both tasks successfully.

Moreover, participants showed significant impairment on all driving performance measures when simultaneously executing a secondary task. Participants drove more slowly, executed more steering reversals, and executed more throttle reversal when performing a concurrent secondary distracting task. These results are particularly significant because the secondary tasks posed relatively light cognitive load. Thus, even tasks that are seemingly not distracting may impair driving performance. Additionally, these results suggest that measures that have been employed in simulator studies translated to a real-life driving environment.

Although the aforementioned measures reflected drivers' performance in this context, we must use caution when interpreting these findings. The current study was designed to examine the effects of visual-manual tasks on driving performance in a specific experimental setting. Other factors may influence driving performance in actual military operational driving environments. For example, our participants consisted of civilians rather than military personnel. Similarly, no participants had experience driving a military HMMWV. Additionally, participants drove at low speeds on a dirt road without traffic, pedestrians, or other obstacles.

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Linguistic cognitive load: implications for automotive UIs

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ABSTRACT
This position paper describes an approach to speech-driven user interfaces for automotive drivers. Drivers divide their attention between hands-free electronic devices and the necessity of driving safely. These devices are often controlled via spoken dialogue interfaces, which impose their own burden on driver attention. We argue for an approach that modulates the complexity of the user interface with ongoing driving conditions using psycholinguistic measures of language complexity, and we describe an overall system design in the context of research into language in divided-attention contexts. Our system design uses a given language complexity metric to calibrate the rate of syntactic and semantic information transfer between the driver and the synthetic speech interface in order to prioritise safe driving while permitting the driver to perform auxiliary tasks.

Categories and Subject Descriptors
J.7 [**Computer Applications**]: Computers in other systems—*consumer products, real time*; H.5.2 [**Information systems**]: Information interfaces and presentation—*natural language*

1. INTRODUCTION
Driving a car is a task that takes a non-trivial portion of the driver's attention and concentration, but technological advances, some now long-standing, permit drivers to perform both auxiliary and unrelated tasks. This presents challenges to the safety and effectiveness of driving to which legislative solutions are increasingly being applied: in particular, strongly enforced requirements for hands-free electronic devices while operating a vehicle.

An obvious solution that represents a compromise between the safety need for two-handed driving with eyes on the road and the driver's desire for increased productivity and control is the use of artificial spoken dialogue-based interfaces to present information and options. But these interfaces also themselves require some amount of attention from the driver, and hence pose potential impediments to the driver's response to road stimuli. Our challenge is to develop interfaces that relate the complexity of spoken system prompts to the amount of attention that the user can afford to pay to a non-driving task.

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Recent results in experimental psycholinguistics suggest that we can indeed relate some component of attention directly to the features of the language being synthesised. There is an established and growing body of psycholinguistic research that provides numerical measures of linguistic complexity during incremental (or real-time) parsing derived from information theory and from the algorithmic complexity of hypothesised human parsers. There is evidence, from eye-tracking and other modes of experimentation, that these measures are correlated with some form of cognitive load.

To use these results in automotive UIs, we are establishing this research program: (a) study of the relationship between divided attention and different levels of linguistic representation (particularly semantic, syntactic, discourse); (b) design of a system to mediate in-car synthetic speech prompt production; and (c) measurement of the effects of in-vehicle dialogue system interaction.

We consider (a) in sections 2 and 3, wherein we introduce some relevant linguistic and psychological concepts and research. We illustrate (b) and (c) in section 4, wherein we sketch out a way forward for in-vehicle linguistic attention control. In section 5, we provide some concluding remarks that summarise our position on in-vehicle speech systems.

2. ATTENTION AND COMPREHENSION
There is some preliminary evidence for the effect of language on the ability to hold attention to a task from work on attention focus and switching. Experiments have shown that synthetic speech can impose different attention requirements on the user as well as different degrees of comprehension when compared to natural human speech. Delogu et al. (1998) showed that human subjects needed to pay more attention to synthetic speech in order to perform well on a comprehension task. We might hypothesise that we could account for this, for example, with reference to phonetic and phonological factors, but further experimentation appears to demonstrate otherwise. More recently, Swift et al. (2002) used eye-tracking measurements to show that there was a difference in the time it took to pay attention to an object

referred to in speech-synthesised instructions than it took in human-voiced instructions if the instruction used a definite article rather than an indefinite article. This suggests a more complex interaction between semantic factors and listener expectations in synthesised speech comprehension.

Both these research efforts used the same text stimulus via natural speech and synthetic speech. In applied contexts, however, the text is going to vary, and our effort is precisely to determine how much to vary it. If linguistic factors in synthetic speech do indeed have an effect on human attention switching, then by varying the generated language, we should be able to limit its deleterious effect on attention during in-vehicle multitasking. This requires that we be able to measure the cost of shifting attention between tasks, particularly when one task is a linguistic interaction task. Fortunately, there is work in unsynthesised speech settings that provides suggestive evidence for these costs.

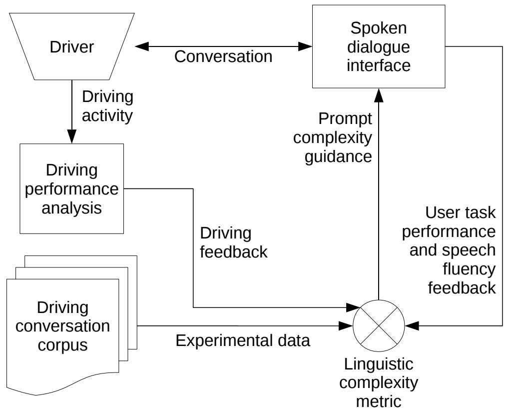
Taube-Schiff and Segalowitz (2005) use an alternating-task experimental framework to show that changes in "grammaticized" words (conjunctions, prepositions, and so on) have an independent effect on the cognitive cost of shifting attention from one task to a different task[1]. Fang et al. (2009) use a language-directed 3D "treasure hunt" simulation with a conversational interface. They demonstrate that the distance between their subjects' gaze fixations over time is mediated by the "smoothness" of discourse transitions from sentence to sentence, where discourse transition smoothness is defined in terms of Centering Theory (Grosz et al., 1995). Centering Theory ranks discourse "centres" partly by relative grammatical roles.

The cumulative effect of these levels of linguistic representation (phonological, syntactic, semantic, pragmatic) is potentially suggestive of an organising principle at work. Some of the sentence processing literature (Frank and Jaeger, 2008) points towards the existence of a limitation on human linguistic information processing. Human linguistic cognition attempts to hold the rate of information flow as close to constant as possible and deploys strategies within the various levels of representation in order to do so.

If that is the case, then we need to design systems that compensate by altering the information flow rate when there is a competing stimulus. Since the above literature has demonstrated that attention switching and focus are affected by linguistic information flow, we would expect these effects to be exacerbated when the other task (e.g. driving) is entirely unrelated. As the primary task consumes more driver attention, the quantity of linguistic information generated by the spoken UI should decrease. A more direct way of putting it would be to say that the interface should produce more concise, information-rich utterances when the driver's attention is less taken by driving, and it should produce slower-paced utterances with information transfer more spread out over time when the driver needs to pay more attention to the traffic.

Then our challenge becomes one of finding the function that mediates this relationship.

Figure 1: Overview of dialogue complexity manager.



3. COMPLEXITY AND COGNITIVE LOAD

The task of a dialogue system is to convey a certain set of facts to the user. However, there are various different ways for how the information can be formulated. User studies have shown that user satisfaction with dialogue systems is negatively correlated with task duration (Walker et al., 2001), suggesting that one should optimise for efficient communication. This is also supported by findings of Demberg et al. (2011), who compared two dialogue systems from the flight booking domain, one of which generated more complex linguistic structures, explicitly pointing out trade-offs between different options while the other generated less complex utterances. The more complex system led to more efficient user interaction, higher task success and improved user satisfaction when users could fully concentrate on the interaction with the dialogue system. When the two systems were evaluated in a dual task setting in a car, users however preferred the less complex system and also had a slightly increased number of minor driving errors (like crossing the line) when using the dialogue system that generated more complex utterances in the "difficult driving" condition (Hu et al., 2007). These findings call for a dialogue system that generates its utterances with suitable complexity in a given situation. In order to do this, we need to know which linguistic structures cause processing difficulty in humans.

A large body of research has shown that processing difficulty can occur at various linguistic levels, such as the structure of sentences, the semantic relationships between words and the discourse cues that link phrases or sentences.

3.1 Measures of sentence processing difficulty

One source of processing difficulty are unexpected linguistic events. A prominent measure of such processing difficulty is surprisal (Hale, 2001; Levy, 2008). Surprisal is defined as the negative log-probability of a word given its context. A highly-predictable word or sentence structure has low surprisal and causes little processing difficulty, while a word or

[1]Taube-Schiff and Segalowitz illustrate this by contrasting "the food remained on the plate because the boy wasn't hungry" with "there was food and a plate and a boy and the boy wasn't hungry." They suggest that the shift in cognitive dimensions invoked by the grammaticized words "on" (spatial) and "because" (causal) create greater distraction than when these words are avoided in describing the scene.

structure which is improbable given its context would cause increased processing difficulty. Surprisal can be calculated at various linguistic levels, such as word n-grams, syntactic structures[2], or semantic representations.

Another factor that has been shown to affect human processing difficulty is the accessibility of previous material when integrating it with new material, as captured by dependency locality theory (DLT; Gibson, 2000). DLT measures the distance between grammatically dependent words in terms of intervening discourse-mediating items. Long distance dependencies thereby cause increased processing difficulty, in particular if people need to keep track of multiple open dependencies at the same time.

Demberg and Keller (2009) have recently developed a model of sentence processing called "Prediction Theory" which combines the expectation-based with the integration-based aspect of processing difficulty in a single theory.

3.2 Extensions to existing models

While computational models that assess processing difficulty related to syntax are available and have been tested (Demberg and Keller, 2008; Roark et al., 2009; Wu et al., 2010; Frank, 2010), there is significantly less work on how to integrate the difficulty measures with semantics (Mitchell et al., 2010), and, to the best of our knowledge, no psycholinguistic model that also includes the effect of discourse referents (like "even", "although", "therefore"). Evidence for the impact of such discourse referents on the effectiveness of human interaction with dialogue systems comes from a recent experiment by Winterboer et al. (2011), who found that the presence of discourse cues in dialogue system utterances helps users compare different options and select the optimal option (the setting was again interaction with a flight booking system). Another challenge thus lies in the development of a theory and model of discourse level processing difficulty.

4. COMPLEXITY MANAGEMENT

4.1 System design

The spoken dialogue interface is guided by the linguistic complexity metric (figure 1), some possibilities for which we described in section 3; it seeks to choose responses from its language generation system based on the magnitude of the metric. In turn, it evaluates the quality of user responses, which becomes a parameter of the metric. The quality of user responses is measured based on two overarching factors: speech fluency and task performance.

Similarly, driving behaviour and attentional requirements are also evaluated and factored into the complexity metric. A key insight is that only the spoken dialogue system can be managed in order that it yield the appropriate amount of cognitive capacity to safe driving.

Initial parameters are set by data collected through experimentation. This last idea is crucial to the operation of the system. Most current applications of language technology are guided by machine learning algorithms based on text and speech corpora. We describe the conditions under which these must be collected in the following section.

4.2 Data collection and experimentation

In order to identify the situations and estimate the parameters under which linguistic complexity affects task performance, we need to construct a parallel corpus of recorded conversation and driving performance information. Then we can correlate the values of the complexity measures and see which ones are most predictive of either driving impairment or difficulty in performing the auxiliary speech task. As graphics technology has progressed, there are increasingly realistic and accessible driving simulator apparatus. It is possible to use these tools to measure performance on driving in terms of deviation from an ideal line in a course.

In fact, the major challenge in data collection is not the recording of driver activity, but the preparation of the linguistic data for statistical analysis. One such effort is Fors and Villing (2011); they describe a Swedish-language in-automotive data collection exercise for human-human dialogue. Their collection and analysis of Swedish conversation found that pause duration during conversations increased for the driver during periods of apparent high cognitive load, measured by the driver's reaction time to a buzzer. Apart from the time and cost of transcribing the speech into text (something which automatic speech recognition may partially solve particularly for more widespread languages like English), Fors and Villing note that identifying the pause boundaries is very time consuming. Recent developments in data annotation such as crowdsourcing, however, now enable us to use unskilled Internet labour to annotate a variety of subtle distinctions (Sayeed et al., 2011); it is a matter of user interface design to present the task in such a way that errors and other features can be annotated by people who have no training in the task.

Once we have driving performance data and speech task performance data aligned over time for a sufficient number of subjects, it is then possible to explore the correlations between quantitative linguistic complexity and driving attention in context. This will allow us to set the parameters of the system in synthesising appropriate prompts.

5. CONCLUDING REMARKS

In this paper, we have brought together a number of elements that belong to a research agenda in in-vehicle spoken dialogue systems, and we have done so in a manner that makes psychologically plausible models of sentence processing relevant to automotive and other dialogue-based control and communication systems. A key component of this is attention and the effect of linguistic cognitive load. Multimodal tasks that involve communicating with an automated system while driving need to modulate the linguistic complexity of the interface with reference to current load and the need to retain a safe level attention on driving.

[2]Here is the canonical example of a difficult-to-process syntactic structure in language science, by way of illustration: "The horse raced past the barn **fell**." Most native English-speakers find this sentence ungrammatical at first glance, because "the horse raced past the barn" is a complete sentence. However, it is also a reduced relative clause, permitting "the horse (that was) raced past the barn fell" after subsequent consideration. "Fell" is a syntactically high-surprisal item. This is an extreme "boundary" case, but linguists have identified more subtle phenomena with similar characteristics.

It happens that there is a large literature on attention and comprehension in the synthetic speech context and in the dialogue context. Different levels of linguistic representation affect or appear to be affected by tasks that demand attention; in particular, syntactic and semantic factors appear to have an effect on human performance in tasks that involve interaction with both synthetic and natural speech. There is also a large literature on computing psycholinguistic complexity and different levels of linguistic representation; divided-attention tasks such as driver multitasking permit this work to be leveraged in an applied context.

Given this scientific background, we have proposed an overall system design for in-vehicle spoken dialogue complexity management. We have also identified some of the design and data collection challenges that need to be overcome in pushing this agenda forward. As yet there is no publicly available corpus that relates transcribed speech data to user task performance and driving performance. However, the technical challenges to this, though significant, are not insurmountable. The final step is the design and construction of variable-complexity in-car dialogue systems.

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Effect of Spatial Haptic Cues on Visual Attention in Driving

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ABSTRACT
We have developed a haptic cue-based navigation system that helps a driver find important traffic signs and obstacles in cognitive overload situations. We conducted a visual search experiment using a flicker paradigm to evaluate the effectiveness of the system. The two independent variables used in the experiment were cue validity (valid vs. invalid vs. no-cue) and level of cognitive load (high vs. low). A haptic facilitation effect was found for visual tasks; the response time was shorter when haptic cues were consistent with the location of visual targets (*valid cue*) than when haptic cues were not (*invalid cue*) or when no haptic cues were presented (*no-cue*). In addition, this crossmodal facilitation effect of haptic cues was found in both levels of cognitive load. This result strongly implies the development of a driving navigation system with spatial haptic cues for various cognitive load situations.

Categories and Subject Descriptors
H5.2. User Interfaces: Evaluation, Haptic I/O.

General Terms
Experimentation, Human Factors.

Keywords
Driving navigation system design, haptic interface, vibrotactile, cognitive load, flicker paradigm

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1. INTRODUCTION
Current navigation systems usually provide visual and auditory guidance. However, there are some visual and auditory obstacles that prevent a driver from acquiring driving related information from a navigation aid. Haptic cues as an alternative modality to this highly cognitive overloaded situation was considered in this study. Haptic cues can be helpful while driving because they do not interfere with other modalities. In addition, there is evidence of a crossmodal facilitation effect of spatial haptic cues on visual tasks [3, 5]. Therefore we designed a novel navigation aid which exploits vibrotactile cues to represent spatial locations in visual search tasks and evaluated the proposed system under various conditions.

2. SYSTEM DESIGN
We have developed a haptic cue-based navigation system using vibrotactile signals to present haptic spatial information during driving. The haptic interface was mounted on the back of a chair because torso is considered to be suitable for rendering spatial information [1].

The haptic navigation system in this study consisted of a tactor array, a controller board and a host computer. The tactor array included 5-by-5 vibration motors. Each vibration motor was located on the latex rubber which reduces the transmission of vibration from a tactor to others. Five tactors on the top and five tactors on the bottom of the tactor array were used to provide directional information for visual tasks: lower right, lower left, upper left and upper right. Tactors were vibrating one after another to indicate four different directions so that participants could easily perceive directional flows of vibration on their backs. The host computer transmitted information about the direction and timing of haptic cues to the controller board, and the controller board drove the tactor array based on the received information.

3. SYSTEM EVALUATION

We conducted a visual search experiment using a flicker paradigm to evaluate the usefulness of the system.

Participants. Sixteen university students (Males: 7, Females: 9) volunteered to participate. Their mean age was 22.4 (SD= 1.7). They did not have any visual or haptic health problems.

Design. The two independent variables used in the experiment were validity (valid vs. invalid vs. no-cue) and cognitive load (high vs. low). As to the validity factor, a vibrotactile cue was defined as *valid* if the directional flow of the vibrating tactor indicated the quadrant where the changing object was presented; a vibrotactile cue was defined as *invalid* otherwise; *no cue* was without any vibrotactile cues presented. The occurrence ratio between the valid haptic cues and invalid haptic cues was 3 to 1 throughout the entire experiment. The visual cognitive load factor had the two levels of depending on visual complexity. Visual scenes with highly dense objects were defined as a *high* overload condition, because visual search tasks with those scenes were expected to be difficult [4]. Visual scenes were otherwise defined as a *low* level of cognition overload condition. The level of cognitive load of each visual scene was examined in the pilot test. The occurrence ratio between the high and low cognitive load conditions was the same throughout the experiment.

Procedure. First, they conducted a practice session where they could become aware of vibrations and clearly identify the direction of vibrations presented on their back. The visual change-detection task consisting of two blocks of 28 trials conducted after the practice session. For each trial, a fixation point was presented in the center of the screen at the beginning, and then a vibrotactile cue was rendered. After a short pause, the visual change-detection task began. During the task, an original photograph and a modified photograph which contained only one different object were repeatedly alternated and presented to participants. We asked participants to find and locate changing objects on the host computer's screen as quickly as possible, and their response times were recorded for analysis. Visual stimuli were presented until participants found changing element.

4. RESULT

Response times for each condition were recorded during the experiment and used as dependent variables in analysis. A two-way repeated-measure ANOVA with validity (valid vs. invalid vs. no-cue) and cognitive load (high vs. low) as within-subjects factors was carried out.

The analysis showed that the main effect of validity was statistically significant ($F(2,30)=42.54$, $p<0.001$). The result indicated the usefulness of the vibrotactile cue for the visual search task. The main effect of cognitive load was also significant ($F(1,15)=90.20198$, $p<0.001$). Response times were significantly shorter in the low cognitive load condition than in the high cognitive load condition. There was no significant interaction effect between validity and cognitive load.

Pairwise comparisons for validity showed that the response times in the valid cue condition was significantly shorter than in the invalid cue condition and also in the no-cue condition ($p<0.001$). The analysis also showed that the vibrotactile cues for conveying spatial information were useful for both levels of visual cognitive loads.

5. CONCLUSION

In this research, we designed and evaluated the haptic cue-based driving navigation system which uses vibrotactile cues to present spatial locations in the visual task. The result showed the efficiency of haptic cues in a visual search task while driving.

Valid haptic cues facilitated the participants' performance, elicited shorter response times in visual search tasks than invalid and no haptic cues. This crossmodal facilitation was found in both high and low cognitive load conditions. In other words, the vibrotactile cues for spatial information were efficient for any level of visual cognitive loads in the driving situation. The result of this research implies the development of haptic cue-based driving navigation system.

For future work, more research on the crossmodal facilitation of haptic cues under various visual tasks is necessary. In addition, the crossmodal interaction of haptic and auditory or haptic, visual and auditory should be dealt to provide a guidance in designing of future navigation systems.

6. ACKNOWLEDGMENTS

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Design and Make Aware: Virtues and Limitations of Designing for Natural Breakpoints in Multitasking Settings

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ABSTRACT
Drivers are frequently observed interacting with in-car devices despite the well-documented dangers and (financial) penalties of such behavior. It is therefore useful to think about how to make such in-car multitasking situations safer. In this position paper we discuss how the consideration of "natural breakpoints" in tasks can be useful. We discuss the virtues of designing for such breakpoints, but also highlight limitations especially related to people's awareness of their performance.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**] User Interfaces: Theory and methods; H.1.2 [**Information Systems**] User/Machine Systems: Human factors

General Terms
Performance, Design, Experimentation, Human Factors, Theory

Keywords
Natural Breakpoints; Performance Trade-offs, Multitasking

1. INTRODUCTION
In-car multitasking such as dialing while driving is observed frequently [18], despite over twenty year of research that has highlighted the dangers and despite legal bans [e.g., 7]. Given this natural urge for people to multitask in the car, the research community should consider ways to alleviate some of the problems associated with it. In this position paper, we discuss how designing in-car applications with "natural breakpoints" in mind might be valuable, and what limitations to such an approach are.

2. NATURAL BREAKPOINTS
Multitasking requires people to divide their attention between multiple tasks, such as between a phone conversation and control of the car. Although sometimes users can perform tasks truly in parallel, typically they can mostly focus on one task at a time as cognitive, perceptual, and motor resources are limited ([20], see also [17]). For example, in a driving situation the eyes cannot look at both the road and at the display of the radio. Due to these resource bottlenecks, multitasking often inherently requires people to make a performance trade-off in when to dedicate a resource to a task [14, 15]. Dedicating a resource to a task can improve performance on that task, but might be at the cost of performance on another task. How do people make such trade-offs? That is, how do they decide when to switch their attention?

One factor that can guide this process is the task structure. Goal directed tasks can often be decomposed in a hierarchical manner [6] with higher level goals (e.g., making coffee) being decomposed into subgoals (e.g., pouring water into the coffee machine), which are decomposed into even smaller steps (e.g., opening a lid). Research has shown that in multitasking situations people are likely to interleave at "natural breakpoints", where one subtask has been completed and the next subtask is still to commence (e.g., [2, 16], for more discussion see [11, 12]).

2.1 Virtues
Interleaving at natural breakpoints compared to other positions in the task hierarchy offers many advantages (see also [11, 12]). First, switching attention after subtask completion avoids the need to remember details (to aid future resumption) about the state at which a task was abandoned [3]. This reduces mental workload [2]. Second, this also avoids having to later retrieve this information, which makes task resumption faster [1]. Third, when a subtask is finished, resources are no longer needed for completion of the subtask. These then become available for other tasks, which avoids resource bottlenecks [20]. Fourth, interleaving at natural breakpoints compared to other points can also be explained because this can offer a speed-accuracy trade-off [4, 11, 12]. Here the time cost to switch between tasks (e.g., the time needed to switch attention and to resume a task) is minimal, which makes it less costly to switch here compared to at other points.

Given these benefits, it is worthwhile for designers of in-car systems to consider where the natural breakpoints in their products are. That is, it is useful to think about the task hierarchy. Recent systems have done this, by considering natural breakpoints in deciding when to provide users with system-driven interruptions (e.g., when to provide an e-mail alert) [9].

2.2 Limitations
Unfortunately, there are limitations to the use of natural breakpoints as a means to encourage task interleaving. In our lab we conducted studies in which participants had to steer a simulated vehicle while also performing secondary tasks (typically, manually dialing a phone number). We found that people's use of natural breakpoints depended strongly on their priorities. Drivers that set safe driving as their priority made use of the natural breakpoints to interleave secondary tasks for driving [4, 11, 12]. However, drivers that set fast completion of the secondary task as their priority omitted interleaving that task for driving completely [4], or interleaved only at some of the natural breakpoints [11, 12]. This implies that designing tasks to

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incorporate natural breakpoints will only influence performance when users set appropriate priorities (i.e., “safety first”).

A second problem is to choose the right amount of breakpoints. In a study where multiple breakpoints were provided we again found that people use these breakpoints [12]. However, they did not use all of them. This was probably because additional interleaving did not improve performance strongly. Future work should point out to what extent people can be guided in other ways (for example using feedback [13]) in how they make performance trade-offs.

3. GENERAL DISCUSSION

In this paper we have taken the position that considering natural breakpoints when designing in-car devices can be beneficial. Interleaving at natural breakpoints offers users many advantages, and people show a tendency to interleave here. Good design might therefore encourage how frequent people interleave between tasks by providing sufficient breakpoints. In the context of in-car systems this might make the difference between a driver that checks the road frequently and one that ignores the road altogether. However, there are limitations to this approach. Most importantly, drivers who don’t set safety as their priority tend to ignore cues for interleaving. It is therefore important to make them aware of the impact of multitasking on safety [see also 19].

A limitation of our studies is that they were conducted in a lab setting. Surely in the real-world people’s priority is always to drive safely? Unfortunately this doesn’t seem to be the case. Closed test track studies have shown that people multitask in the car, even when they have full knowledge about future safer (non-multitask) opportunities to perform a secondary task [8]. Similarly, in-car phone use is still observed frequently [18].

A complementary design solution to our work is to reduce drivers’ need to make performance trade-offs altogether. For example, phones that have speech interfaces reduce the need to share visual and manual resources between the phone and the road. However, this approach also has limitations. First, the reduction of visual-manual interaction does not necessarily make it safe to make a phone call while driving (e.g., [10]). Second, even when “safer” interfaces are available, users might not always choose to use them, if the interaction style does not serve their objective. For example, audio interfaces might reduce visual distraction, but can also be slow to use compared to visual interfaces. Users might therefore choose to use a visual interface over an audio interface if they want to complete a task quickly [5]. Due to these limitations it is still worthwhile to think about natural breakpoints in tasks.

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Investigating the Effect of Cognitive Load on UX: A Driving Study

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ABSTRACT

Cognitive load (CL) and user experience (UX) are understood to be critical in the automotive domain, little evaluation has taken place regarding the investigation of the effect of CL on UX in this domain. This position paper introduces a study plan and research goals that aim to investigate whether and how different levels of CL influence UX, using a driving simulator. Besides a discussion of theoretical background and related work, we present initial results regarding an appropriate experiment design and how to manipulate and measure these variables in our specific study context. The paper concludes with a summary and outlook on next steps.

Categories and Subject Descriptors

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

General Terms

Measurement, Design, Experimentation, Human Factors.

Keywords

automotive, cognitive load, user experience, driving simulator, experimentation, case study

1. Introduction

The concepts of mental workload, i.e., cognitive load (CL), and user experience (UX) are widely recognized to be critical in the automotive domain. CL in this domain is often tied to attentional resources and safety issues, whereas UX is mainly related to design issues. It has been previously established that high CL influences driving performance [3], but is the driver's perception of their experience with using in-car devices (UX) while driving also influenced by CL? To our knowledge, little evaluation has taken place regarding the investigation of such an effect of CL on UX, especially in the automotive domain.

This position paper introduces our current research aimed at conducting a controlled experiment in a driving simulator to investigate the effect of CL on UX. The main research questions that underlie our work include: (1) is there a relationship between CL and UX (as exemplarily illustrated in Figure 1) (2) If so, how strong is this relationship? (3) Does this relationship evolve or change over time, especially regarding different driving situations (easy, moderate, hard), different user interfaces (UIs) (graphical or tangible Uis), or different input methods (speech, touch) to interact with a device in a car (e.g. navigation system). However, in order to investigate all these research questions, the first challenge to be solved is related to the design of such an experiment, in particular: how to manipulate and measure these "human-oriented" variables CL and UX in a driving simulator.

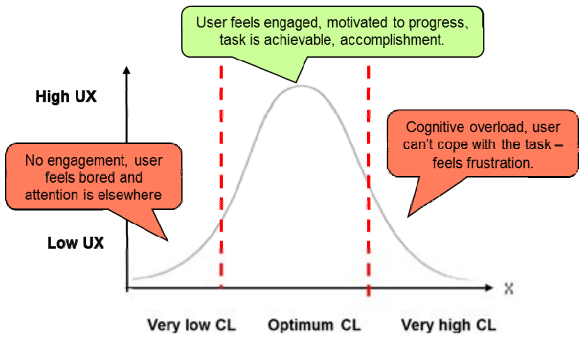

Figure 1: Possible relation between CL and UX

Gaining knowledge about the relationship between CL and UX and suitable measurement and recording techniques for CL and UX could be beneficial in several ways: (1) knowledge about the relationship could be integrated into software engineering approaches, e.g. in forms of guidelines or design decisions for devices which adapt best to a user's CL and still provide a reasonable or high UX. (2) suitable measurements could be integrated into requirements engineering and/or interaction design approaches to derive solutions to lower CL and thus increase UX, (3) the identification of the most appropriate input method, perception modality, and output media according to the level of CL, which influences the UI design could be supported, and (4) CL could be adapted to current driving situations by providing adequate UI designs in order to optimize UX in that situations.

In the following, we describe the theoretical background of both CL and UX in the context of automotive research and related studies in this field. This is followed by a description of current efforts to design such an experiment and select appropriate measures. We conclude this paper with a short summary and outlook on next steps.

2. Background and Related Work

2.1 Cognitive Load

CL is variously described as the level of perceived effort associated with thinking and reasoning by a user, to complete the task successfully [2]. It is well-established that the two main limitations of working memory resources are its capacity and

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duration [2]. Only a limited number of item "chunks" can be held in working memory at any one time and then only for a short amount of time [5]. These limitations are never more evident than when users undertake complex tasks, or when in the process of learning – resulting in extremely high demands being placed on working memory. The construct of CL refers to the working memory demand induced by a complex task in a particular instance where novel information or novel processing is required [15]. The CL construct comprises at least two separate load sources: intrinsic load and extraneous load. Intrinsic load refers to the inherent complexity of the task; whereas extraneous load refers to the representational complexity – that is, complexity that varies depending on the way the task is presented. In an automotive system, the task complexity would be dictated by the domain. For example, a sample task might be driving on a rainy day at night, while listening to the radio or following GPS instructions. The tools and interfaces the driver employs to complete the task, e.g. a steering wheel with cruise control, a paper based directory, or even Google maps on their iPhone, contribute to extraneous load. Situations that induce high levels of CL can impede efficient performance on designated tasks [15].

Since the capacity of working memory is limited, the user's CL should be maintained below a safe threshold to prevent task failure [16]. A number of methods have been used, both in HCI and other domains, to estimate experienced levels of CL. Existing methods for measuring CL, used separately and in combination, include (1) subjective measures, such as self-rating scales, (2) physiological techniques, such as heart rate [13] and pupil dilation [4], (3) Task or performance based measures, such as critical error rates; and (4) Behavioral measures, such as linguistic indices [8].

Unfortunately, many of these data acquisition and analysis methods are highly intrusive and can disrupt the normal flow of the task, or are physically uncomfortable for the user. Historically, the most consistent results for CL assessments have been achieved through self-rating subjective measures; however, the assessments can only be made available offline after completion of the task. Among the other types of methods, behavioral methods appear to be the most suitable for practical CL monitoring systems which need accurate, non-intrusive, objective and real-time measures. Speech features can be a particularly good choice within behavioral methods, since speech data already exists in many real-life tasks (e.g. telephone conversation, voice control) and can be easily collected in a non-intrusive and inexpensive way [16]. However, while most of these types of measures are suitable for research purposes, many are unfeasible for automotive applications.

2.2 User Experience in Cars

UX as a concept is well known and widespread in the field of UI design, ranging from software design, website design, mobile devices etc. The definition of UX itself is rather controversial, but it can generally be described as the experiences a user has before, while or after interacting with a product, system, service or object [10]. These experiences include all kinds of subjective perceptions such as emotions and cognitions as well as behaviors. Furthermore, the context in which the product is used influences how the user perceives experiences with the product. To conclude, UX is a multidimensional and complex construct which cannot be assessed with a single item questionnaire. Recently, UX became increasingly important especially in the automotive domain: A comprehensive description of input and output devices in a car with regard to placement and modality was created in [7]. That design space provides a basis for analyzing and discussing different UI arrangements in cars, enables the comparison of alternative UI setups and the identification of new opportunities for interaction and the placement of controls. The newly formed design space comprises considerations about input and output modalities, recommendations for instantiations the usage of different interface objects, and guidelines for the positioning of input and output devices.

A deeper understanding of how drivers concretely interact with today's entertainment, communication, navigation, and information systems in their cars and how they balance those interactions with the primary driving task is gained by General Motors' UX design team's contextual design project "Journey" [6]. One important conclusion drawn from the project was that too often driving was the least important thing in the car. Drivers are distracted by conversations, navigation and entertainment adjustments, addressing needs of passengers, and getting environmental information. Furthermore, the authors claim that UX depends on the brand of the car: expensive vehicles are expected to provide easy to use functionalities and a driver should experience the higher-quality aesthetics compared to those of lower tier vehicles from the same manufacturer.

Another approach for designing experiences while interacting with an advanced driving assistance system is introduced in [9]. It aims at creating positive UX by a story-based design workflow. Hereby, UX focusses on the fulfillment of psychological needs, so psychological needs have to be identified which can be important when interacting with advanced driving assistance systems and systems are designed based on that needs. The workflow can be described as follows: based on results of *collecting positive driving experiences* that emerged from critical situations (by interviews and PANAS-based questionnaire), *UX schemes are identified* that integrate several actual experiences and their specific psychological needs. Afterwards, a *fictional UX story of a positive experience is created* for each UX scheme and a corresponding *UX storyboard is created*. Finally, *design ideas are implemented* in a simple driving simulation based on the traffic scenarios described in the UX stories.

Until now, the majority of driving simulator studies have been related to safety issues, e.g., how driving performance is influenced by performing a secondary task, such as using a mobile phone while driving [3], or what kinds of psychophysiological data could be used as an input for driving assistance devices, e.g. face recognition to detect different states of emotion or brain waves to predict driver intentions etc. However, studies investigating UX in such a driving simulator context are still hard to find. In order to plan and conduct an experimental study which could answer our research questions, we are primarily interested in how experimental variations of CL and data collection for CL as well as UX has been done by other researchers and which measurement methods are recommended.

One study which relates to our study objectives was performed by Liu [11]. The author examined driver performance and subjective ratings on workload for young and elderly drivers under high and low-load driving conditions. Additionally the drivers had to respond with either a navigation or a push button task to a simple or complex advanced traveler information system (ATI), with which information was presented in three conditions: only visually, only aurally or multimodal (both visually and aurally).

The driving load conditions resulted by varying driving load factors, e.g. lane width, road type, and traffic density, while information complexity was varied by the number of information chunks presented (little vs. lot) in the ATI. Methodologically, objective measures (e.g. response time, variance in steering wheel position) and subjective measures (system preference and SWAT workload assessment: time stress, visual effort, psychological stress) were assessed. The subjective data collection took place at the midpoint and the end of each scenario (combination of driving condition, task and information system), which means that the driving performance in the driving simulator was abruptly interrupted with filling out a questionnaire for several times, whereas the objective measurement was collected automatically by the driving simulator system itself. The author showed that there were significant differences in the performance measures (e.g. response time, subjective workload) for the different display types: auditory and multimodal displays produced a better driving performance. Also the visual display was a distraction for the driver's attention, which resulted in a less safe driving behavior. The multimodal display of information was preferred by the participants over the two other possibilities.

A general measurement recommendation is given by [12] which can be applied to the automotive domain when considering secondary tasks, which generate distraction and additional CL. They compared concurrent thinking aloud (CTA) with retrospective thinking aloud (RTA) in combination with eye-tracking to analyze a website's usability. They concluded that the use of CTA is reactive in terms of significantly influencing relevant eyetracking parameters, e.g. fixation duration or number of fixations, whereas this does not account for RTA. Also the authors claim, that the use of CTA causes a less natural study situation compared to RTA. RTA on the other side is a more time and resource-consuming technique, but should be used, when natural user behavior is of main research interest.

3. Initial Results

3.1 Experiment Design

Initial discussions towards a suitable design revealed that there were many variables that could be manipulated (like driving task levels, UI designs, driving scenarios, user groups, etc.) which quickly resulted in a design requiring more than 300 participants to discern whether any relationship existed. To handle this complexity we came up with a simpler design in which we first

			Set 1	Set 2	Set 3
A	Task	easy	X	X	X
		medium			
		hard			
B	Driving scenario	baseline (no driving)			X
		driving (normal condition)	X	X	
		driving (hard condition)			
C	UI Design	DesignA	X		X
		DesignB		X	
D	User group	normal	X	X	X

Figure 2: Exemplary set of conditions

define sets of conditions as groups of independent variables (see Fig.2). Furthermore, we add an additional independent variable for CL (such as a secondary task), which will uniformly increase the CL manipulation when present. Based on these variables we will define several designs in which the set is fixed but the CL variable is manipulated and run repeated-measures (within-subjects) studies on each design and measure the UX on the outcomes, i.e., whether there is a change in UX (see Fig.3). Based on such a design we will be able to answer interesting questions as for instance whether the UX varies as CL varies when interacting with a given secondary system (e.g. navigation system).

			Design 1	Design 2	Design 3
A	Set	Set 1	X		
		Set 2		X	
		Set 3			X
B	Cognitive Load (secondary task)	no (Baseline)	X		
		Low	X	X	X
		Medium	X	X	X
		High	X	X	X

Figure 3: Experiment Design

3.2 CL Measurements

Speech is an implicit, non-intrusive data stream that reflects changes in cognitive load – it does not require any overt action by the user (e.g. self-report scales) that may interrupt task flow – hence is suitable for driving tasks. An automatic CL measure from speech in real-time, previously developed by [16] will be used to assess whether the CL manipulation is effective. This means that speech will be required in all conditions.

This measure of CL relies on the classification of speech features using pattern recognition techniques after splitting speech data into discrete levels (e.g. high and low). This strategy correlates each load level to an individual class of speech. Given sufficient training instances, the designed CL levels are modeled by corresponding speech class models, as illustrated in Figure 4. We will also be able to compare the load levels induced by each "UI design set" and the relative differences in CL induced between design sets.

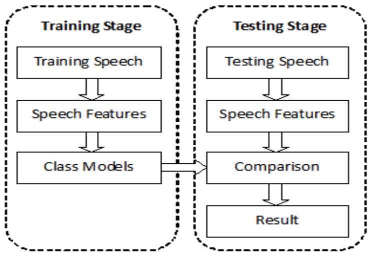

Figure 4: Typical statistical classification system diagram

The classifier works by evaluating each target speech segment such that the likelihood between input speech and models is maximized, so as to determine its CL class [16]. The speech classifier has a number of advantages, such as: (1) automatic CL measurement derived from speech, that can be generated in real-time, (2) automatic model creation from pre-classified speech without manual labelling or analysis, (3) speaker-independent measurement, there is no need to create a model for each individual subject, and (4) novel use of the background speech model to support the solution. Further details of this system can be found in [16].

3.3 UX Measurements

The driving simulator poses some constraints on measurement possibilities. It would be inconvenient for the experiment flow, if a study participant had to interrupt his driving behavior to fill out a questionnaire about the momentary emotional state and impressions right after using a technical device. Also, methods which rely on speech output by the participants such as CTA are not suitable here, because the speak channel is occupied by controlling the inducement of different levels of CL (manipulation check). We are aware of the fact that every driving situation creates CL, which is increased with each secondary task performed in parallel. To minimize the CL created by secondary tasks that are not objects of our inquiry we are not going to let participants think aloud or press any buttons for the conveyance of their current state of UX when driving or let them fill in a questionnaire while or shortly after a single driving task.

A better alternative would be a combination of multiple non-obtrusive measurement options with state-of-the art methods to gather data regarding UX. Hence we basically follow a threefold approach: (1) use of a *combination of objective psychophysiological measurements during driving*: by measuring electrical indicators and non-electrical signals, conclusions can be drawn on (un-)conscious psychological processes. Examples include variables of the cardiovascular system (e.g. heart rate), emotions (e.g., via skin conductance, face detection), muscular or respiration activity, and eye movements [13], (2) use of *standard questionnaires* (e.g., SAM, PANAS [1]) *right after driving*, to measure the overall emotional state and (3) *RTA* while watching videos of the participant's driving performance combined with displaying the data from psychophysiological measurement after driving as a trigger.

Furthermore, we would like to adapt and use the story-based design workflow ([9] and Section 2.2) for both the selection of a driving situation which may create a positive UX (as reference value) and the RTA of the UX. That is, we will interview participants after the driving tasks, let them fill in PANAS-based questionnaires, and let them describe if their psychological needs have been fulfilled when they had been in the simulated driving situation. At this point, the thinking-aloud method can be applied: when they retrospect the UX story in their minds, the subjects comment every situation they remember. It will not matter if they remember situations that really happened or if situations are observed to be more negative or more positive than the subjects estimate afterwards. UX is an ongoing estimation of stimuli in particular situations and thus can be influenced by many other factors like surroundings, mental states, or similar experiences. What matters with UX is the subjective estimation of situations, not the objective, empirical observation. That is why our approach of evaluating the UX retrospectively can lead to comparative results of our experiment.

4. SUMMARY AND NEXT STEPS

This paper introduced theoretical background and initial results of our ongoing research aiming to investigate whether and how different levels of CL influence UX in a driving simulator. Next steps include to test the suitability of the measurements in smaller case studies (e.g., driving tasks with wii) and prepare experimental material. The experiment itself is planned to be conducted in January 2012.

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Utilizing Pupil Diameter to Estimate Cognitive Load Changes During Human Dialogue: A Preliminary Study

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ABSTRACT
In-vehicle spoken dialogue systems are gaining in popularity. However, it is not always clear which system behaviors might result in increased driver cognitive load, which in turn could have negative safety consequences. In this paper we explore the use of pupil diameter to help in the evaluation of the effects of different dialogue behaviors on the cognitive load of the driver.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces

General Terms
Measurement, Experimentation, Human Factors.

Keywords
Eye tracking, pupillometry, cognitive load, driving simulator, dialogue.

1. INTRODUCTION
When developing a spoken dialogue system (SDS) for interactions with in-vehicle devices, designers have to decide on a number of characteristics of the SDS. These include the types of utterances to use, the timing, pace and volume of utterances, as well as how to handle switches between topics. We propose that the design process can be based on the characteristics of human-human dialogues, specifically those in which one conversant is operating a simulated vehicle.

One problem with using human-human dialogues is that we are likely to encounter a multitude of behaviors. Which ones should an in-vehicle human-machine interface (HMI) emulate? We expect that different dialogue behaviors will result in different levels of cognitive load experienced by the driver. We propose using human behaviors that do not unduly increase the cognitive load of the driver. One physiological estimate of cognitive load is pupil diameter. Unlike driving performance, we expect that pupil diameter will be sensitive enough to provide insight into how the different (rapidly changing) behaviors influence cognitive load.

In this preliminary study, we want to determine if we can use pupil diameter to detect major changes in cognitive load during a less-structured verbal task. We feel that less-structured verbal tasks are more representative of future HMI interaction than highly structured tasks (e.g. question-answer tasks). Furthermore, less-structured dialogues are likely to result in more complex dialogue behaviors, accompanied by more complex changes in cognitive load, and thus pupil diameter, than highly structured tasks. A key research question is how pupil diameter changes might be used to estimate the cognitive load related to behaviors that conversants employ in less-structured dialogues.

In this paper we will determine if we can detect differences in cognitive load between times when the driver is engaged in a verbal game with a remote conversant, and after the game finishes. Our hypothesis is that, once a game finishes, drivers will experience reduced cognitive load, and that this will be reflected in decreased pupil diameter.

2. BACKGROUND
In experiments conducted by Iqbal et al. [1; 2] participants performed manual-visual tasks in front of a computer screen. The authors found that the percent change of pupil size (PCPS) correlated well with the mental difficulty of the task. More complex tasks resulted in higher values of PCPS compared to easier tasks.

Schwalm et al. [9] conducted a driving simulator study in which study participants performed the standardized lane change task [5] and an additional visual search task. The authors explored the relationship between driving performance, and the index of cognitive activity (ICA). The ICA is calculated based on the characteristics of minute dilations of the pupil [4]. Driving performance was estimated using the mean difference between the path followed by a participants vehicle and a so-called optimal path. The study found that the ICA correlates well with driving performance: when the additional visual task was introduced, driving performance decreased and the ICA increased.

Both Iqbal and Schwalm used a high precision head-mounted eye tracking system (EyeLink 2). While head-mounted eye trackers are useful for precise eye measures, they can affect the results of the experiments [4]. Thus researchers have turned to remote eye tracking to estimate the cognitive load of the driver. Recarte and Nunes [8] used remote eye tracking in a naturalistic driving experiment in which participants performed secondary mental tasks. Pupil diameter measures showed differences between secondary task and no secondary task conditions.

Recently, Klingner et al. [3] reported on estimating cognitive load using remote eye tracking in front of a computer screen. Cognitive load was manipulated by instructing participants to perform tasks requiring mental multiplication, digit sequence repetition and aural vigilance. The authors concluded that using remote eye

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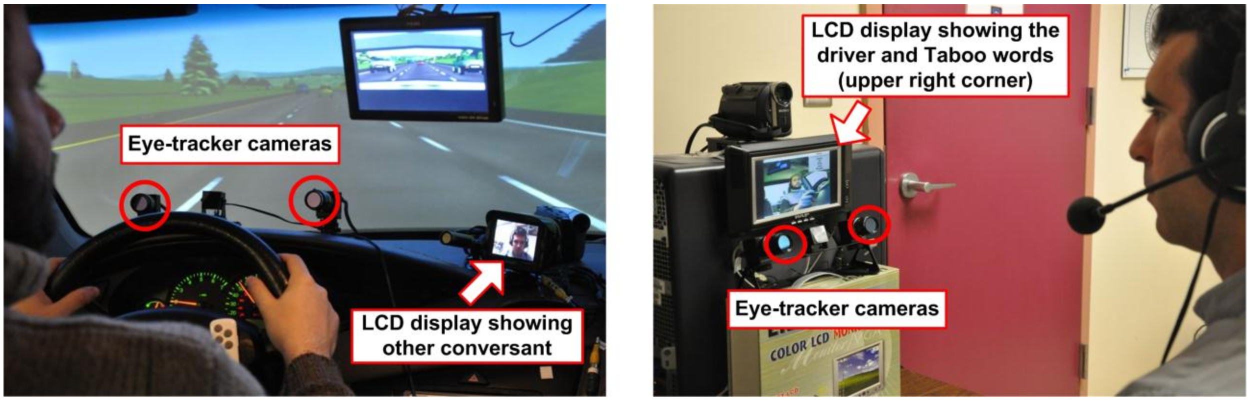

Figure 1 Driver and other conversant.

tracking is a viable way to measure pupil diameter for estimating cognitive load. Building partly on the results of that work, in past work we used a remote eye tracker in a driving simulator experiment to estimate the cognitive load of the driver while he is engaged in a spoken dialogue with a remote conversant [6]. Our pupillometric data indicated that cognitive load changes rapidly (within seconds) between different parts of the dialogue. Specifically, our participants played the last-letter game, in which participants have to utter a word that starts with the last letter of the word uttered by the other participant. During this game the driver's cognitive load estimate was higher when it was the driver's turn to speak than when it was the remote conversant's turn to speak. In contrast to this prior work, the current paper reports on results obtained when the conversants engage in a less-structured verbal game. This is an important distinction, as less-structured dialogues are likely to result in more complex dialogue behaviors than highly structured tasks. For example, in the last-letter game conversants took turns saying one word at a time, and they almost never interrupted each other. In contrast, in the current work, conversants used a variety of dialogue behaviors, for example those related to utterance delivery, such as pausing, fillers, and repetition disfluencies.

3. EXPERIMENTAL SETUP

In our experiment pairs of subjects (the *driver* and the *other conversant*) are engaged in a spoken dialogue. Additionally, the driver also operates a simulated vehicle.

3.1 Equipment

The driver and other conversant (see Figure 1) communicated using headphones and microphones. Their communication was supervised by the experimenter and synchronously recorded as a 48000 Hz mono signal.

The driver operated a high-fidelity driving simulator (DriveSafety DS-600c) with a 180º field of view, realistic sounds and vibrations, a full-width cab and a motion platform that simulates acceleration and braking. We recorded pupillometric data using a SeeingMachines faceLab 5.0 stereoscopic eye tracker mounted on the dashboard in front of the driver.

3.2 Method

3.2.1 Participants

To date the experiment was completed by 12 male participants (6 pairs) between the ages of 18 and 21 (the average age was 19.5). Subjects were recruited through email advertisement and received $20 in compensation. We plan to recruit two more subject pairs.

3.2.2 Driving task

Drivers drove in the middle lane of a three-lane highway in daylight. The highway had both straight and curvy segments. Each driver was instructed to follow a lead vehicle at a comfortable distance. The lead vehicle traveled at 89 km/h (55mph). There was also other traffic on the road travelling in adjacent lanes; however, the traffic did not interfere with the driver or the lead vehicle.

3.2.3 Spoken task: Taboo

The spoken task was the game of "Taboo," a game in which the other conversant is given a word, and needs to work with the driver to identify it, but cannot say that word or five related words. Participants played a series of Taboo games. We provided the words to the other conversant by displaying them on an LCD monitor, as shown in Figure 1. We imposed a time limit of 1 minute on each game.

The experimenter signaled the end of each Taboo game with an audible beep (0.5 second long, high pitched sine wave) heard by both conversants. The end of a game was reached in one of three ways:

- when the driver correctly guessed the word,
- when the other conversant used a taboo word, or
- when the conversants ran out of time.

The spoken task was played using two interaction conditions. In the *voice-only* condition the conversants could not see each other, and so could only use verbal communication. In contrast, in the *video call* condition conversants could also see each other on LCD displays.

3.2.4 Procedure

After filling out the consent forms and personal information questionnaires, participants were given an overview of the driving simulator, the Taboo game, and descriptions of the *voice-only* and *video call* conditions. Next, they completed two Taboo experiments, one for each interaction condition. Before each condition, we provided participants with about 5 minutes of training using that interaction condition. For training, participants completed Taboo games. In order to circumvent order effects, we plan to counterbalance the presentation order of the interaction conditions between eight participant pairs. However, in this paper we present preliminary results based on six participant pairs.

Each interaction condition was preceded by a short drive on a straight highway, which we used for training purposes for the given interaction condition. For both interaction conditions, participants drove a different route. Both routes started with a straight segment, which we used to establish baselines for our dependent variables. In the first route this initial straight segment (baseline) was followed by another straight segment and then a curvy segment. For the second route the initial segment was followed by the curvy and then by the final straight segment. The two routes were of the same length (about 15 km) and complexity. On average it took about 11 minutes to traverse a route. The presentation order of routes was the same for all subjects (but the interaction condition was varied).

After each interaction condition participants filled out a NASA-TLX questionnaire. Finally, at the end of the experiment, participants ranked their level of agreement with various statements pertaining to the interactions and provided written and verbal feedback about the experiment.

3.2.5 Design

In this paper we focus on the simplest scenario in our experiment: *voice-only* interactions on straight roads. From the perspective of pupil diameter measurements, *voice-only* interactions are simpler than *video-call* interactions, as we expect that in the *voice-only* condition the driver will keep his eyes on the road almost all the time. On the other hand, in the *video-call* condition, the driver might cast glances at the LCD display during verbal games, which may introduce noise in the pupil diameter signal as a result of changes in gaze angle and lighting conditions (simulator screen vs. LCD screen). At the same time, we expect that driving on straight segments will induce less (or at most as much) cognitive load as driving on curvy segments. Thus, as a result of driving alone, on straight segments the driver's pupil diameter should be smaller than (or at most as large as) on curvy segments. As pupil diameter is bounded, this smaller diameter is advantageous, because it allows for expansion due to increased cognitive load (due in turn to different dialogue behaviors) to be more pronounced.

We measured multiple dependent variables, of which in this paper we only report on the following:

- Dialogue characteristics: number of games completed, number of games completed successfully (driver correctly identified the word), game durations, and length of time from the end of a game (beginning of the beep) to the first contribution of the other conversant for the next game (excluding any fillers or other stalling devices).
- Cross-correlation to detect changes in pupil diameter after beeps that signaled the end of a Taboo game.

3.2.6 Measurement

Using an eye-tracker we obtained pupil diameter data. The sampling frequency of the eye-tracker was 60 Hz.

We recorded all dialogues in wav files and all beeps as log files created by custom software.

3.2.7 Calculation

Data segmentation: Using the time instants when the beeps started, we segmented each experiment into individual games. We performed calculations and analyze changes in cognitive load based on the pupil diameter data for each individual game.

Dialogue characteristics: From the audio recordings, we manually determined the start time of the first actual contribution by the other conversant. We also counted the number of games completed and the number completed successfully.

Cross-correlation: We estimated the cross-correlation between the beep vector (BV) and the pupil diameter vector (PDV). BV is a sequence of 0s and 1s, where a '1' represents the moment when the beep started (extracted from our custom log files), signaling the end of a Taboo game. Thus, there is a single '1' for each Taboo game. The PDV represents the processed measurements of the driver's left eye pupil diameter. We processed the raw measurements by interpolating short regions where the eye-tracker did not report pupil diameter measures, as well as by custom nonlinear smoothing (e.g. to reduce erroneous dips in pupil diameter caused by blinks).

The cross-correlation between BP and PDV was calculated as the average of cross-correlations for each of the segments and each of the 6 drivers. The lag variable indicates how much the change in pupil diameter lags behind the beginning of the beep signaling the end of the Taboo game. Thus, for positive values of lag, any drops in the cross-correlation function might represent drivers' reduced cognitive load after a beep.

4. RESULTS

The number of games completed by the conversants ranged from 11 to 16, with an average of 13.5. The percentage of successful games ranged from 63% to 100%, with an average of 85%. The game durations ranged from 16 to 24 seconds, with an average of 20.1 seconds. The first contribution by the other conversant happened between 3 and 5.6 seconds after the start of the beep, with an average of 4.6 seconds.

Figure 2 shows the average cross-correlation for all subjects between the BV and the PDV. As hypothesized, the cross-correlation drops in the seconds after the beep is initiated (which is at lag = 0 in the figure). The fact that the cross-correlation drops for about 5 seconds is consistent with the fact that the first contribution by the other conversant started on average about 4.6 seconds after the beginning of the beep (at lag = 0).

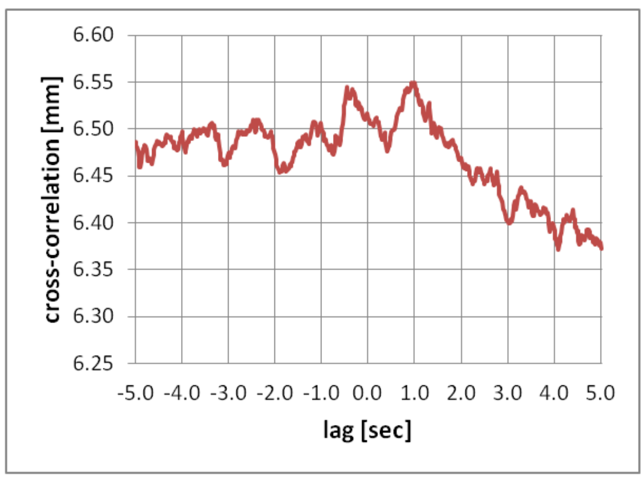

Figure 2 Cross-correlation for all six drivers.

The cross-correlations of two of the six drivers in this study did not clearly support our hypothesis. A number of factors could be responsible, including differences in how the game was played by these participants (e.g. how engaged they were), and the noisiness of the pupil diameter measurements.

Figure 3 shows the cross-correlation (averaged over all segments) for the four drivers whose data did in fact support our hypothesis. In comparison to Figure 2, we can see that the drop is even more prominent. Additionally, the pupil diameter appears to be rising in the seconds before the end-of-game beep. We hypothesize that this rise is related to increased cognitive activity by the driver as he is attempting to find the word described by the other conversant. As correctly identifying this word is the most common cause of the end of the game, and thus the beep, it appears likely that cognitive load would indeed peak before the beep, thus at a negative value of lag. We should also expect to see a peak each time the driver makes a guess, but those peaks are not aligned with each other in time. Thus, they would not be visible after the cross-correlation operation.

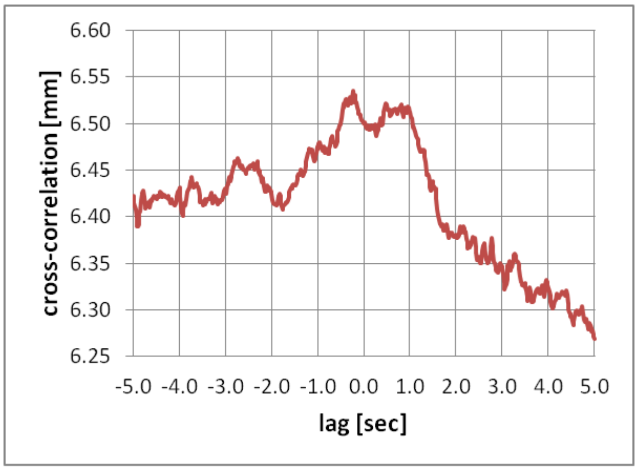

Figure 3 Cross-correlation for the four drivers whose results clearly supported our hypothesis.

5. CONCLUSIONS

The results for four of our six drivers support our hypothesis that pupil diameter can be used to identify major changes in cognitive load during a dialogue. Figure 3 indicates that for these drivers the pupil contracts by about 0.25 mm in the 4-5 seconds after the end of a Taboo game. Note that this effect size is similar to what we observed when we explored structured verbal tasks [6] as well as when we explored pupil diameter changes during an aural vigilance task [7]. These results are encouraging and indicate that using pupil diameter might be a viable approach to estimating the effects of dialogue behaviors on cognitive load changes.

Future efforts on this front should focus on collecting and processing large corpora of human-human dialogues and accompanying pupil diameter measurements. However, before such corpora are to be collected, researchers need to carefully identify potential confounding factors, such as effects resulting from the driving task, from the structure of the verbal task, and other effects on pupil diameter such as those due to changes in lighting (see e.g. [7]). Researchers would also benefit from improved signal processing algorithms for handling the effects of blinks and changes in gaze angle on pupil diameter measurements.

Once we establish the viability of our approach we expect that it will be useful in evaluating the effects of different dialogue behaviors on the driver's cognitive load. We expect that the approach will be useful both in human-human studies, which can result in behaviors that can inspire human-computer behaviors, as well as in human-computer studies, which will evaluate the behaviors implemented in different spoken dialogue systems.

6. ACKNOWLEDGMENTS

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Estimating Cognitive Load Complexity Using Performance and Physiological Data in a Driving Simulator

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ABSTRACT
This paper suggests an algorithm for estimating driver's cognitive workload complexity using driving performance and physiological data. The algorithm adopts radial basis probabilistic neural networks (RBPNN) to construct estimation models. In this study, combinations of two driving performance data including standard deviation of lane position (SDLP) and steering wheel reversal rate (SRR), and two physiological signals including heart rate (HR) and skin conductance level (SCL) were considered as measures of cognitive workload. Data for training and testing the RBPNN models were collected in a driving simulator in which fifteen participants drove through a highway and were asked to complete auditory recall tasks which consist of three levels of difficulty. The best performing model, which uses SDLP and SCL data over a 20s-window, could identify four graded levels of cognitive workload with an average accuracy of 85.6%. The results demonstrated that the model using SDLP and SCL was outperforming than the other combinations among performance and physiological measures.

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

General Terms
Algorithms, Human Factors

Keywords
Cognitive Workload, Cognitive Workload Estimation, Driving Performance, Physiology, Neural Network

1. INTRODUCTION
Identification of a driver's workload and spare capacity is crucial in the design of adaptive automotive user interface [1]. By monitoring driver's workload, the adaptive interface system can provide timely and affordable information when the driver has the spare capacity to understand and respond to it.

Workload refers to the amount of resources that is required to perform a particular task. Two major types of driving workload are visual and cognitive workload [2]. Visual workload is straightforward, but cognitive workload is difficult to measure directly because it is essentially internal to the driver [3].

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Nevertheless, there have been efforts to measure cognitive workload using subjective measures, physiological measures [4], eye movement measures [5], and driving performance measures [1]. Among those measures, driving performance measures can detect the cognitive workload using easy and less expensive methods through readily available in-vehicle information [6]. However, driving performance measures are known to have limitations compared to others due to small changes according to the cognitive workload. That is, the performance measures are able to detect a high cognitive workload condition, but their classification accuracy is not enough to distinguish three levels of cognitive difficulty, which were applied in this study as secondary tasks to add cognitive workload [7].

In the meantime, physiological measures have been proposed as useful metrics for assessing workload in the user interface design and optimization process [3]. Mehler et al. found that when the three levels of task difficulty were randomly ordered, and a recovery interval was provided between tasks, a near linear increase in heart rate and skin conductance appeared across the demand levels [3]. For both heart rate and skin conductance, each task level was statistically differentiated from single task driving and from each other. These findings demonstrate that both heart rate and skin conductance provide the sensitivity to discriminate incremental changes in cognitive workload.

Thus, this paper suggested an algorithm for estimating driver's cognitive workload using driving performance and physiological data, especially the standard deviation of lane position (SDLP) and steering wheel reversal rate (SRR) among performance measures, and heart rate (HR) and skin conductance level (SCL) in physiological data. The results demonstrated that the combination of performance and physiological data, especially SDLP and SCL, can be effectively used as inputs of cognitive estimation models which can distinguish driving only and three levels of dual task conditions at the high accuracy rate.

2. MEASURES AND MODELS FOR COGNITIVE LOAD ESTIMATION

2.1 Driving Performance Measures
Some studies have shown that cognitive distraction undermines driving performance by disrupting the allocation of visual attention to the driving scene and the processing of attended information. Consequently, cognitive workload leads to significantly reduced lane keeping variation and increased response times to sudden obstacles. In this paper, therefore, lateral controllability was used as driving performance measures under

cognitive workload. The lateral position variation and steering wheel activity were selected to assess lateral controllability.

2.1.1 Lateral position variation

Lateral position variation is one of the most commonly used driving behavior metrics. Reduced variation in lateral position when engaged with a cognitive task could be interpreted as a symptom of driver overload and increased risk of incorrect decisions. Lateral position variation can be calculated as the standard deviation of lateral position (SDLP). In this paper, a high pass filter with 0.1 Hz cut off frequency is applied on lane position data to reduce dependency of data length.

2.1.2 Steering wheel activity

Cognitive secondary tasks yield increased steering activity. The increase is mainly in smaller steering wheel movements, the majority of which are smaller than 1 degree. The steering wheel reversal rate can be used for measuring the increase of smaller steering wheel movements. It is defined as the number, per minute, of steering wheel reversals larger than a certain minimum angular value, i.e. 0.1 degree.

2.2 Physiological Measures

In some situations physiological indices may be more sensitive than performance-based measures for detecting initial changes in mental workload [3-4]. That is, physiological measures may show increased activation before the appearance of significant performance decrements. Mehler et al. selected heart rate and skin conductance (sweat gland activity) as primary measures of interest, because those measures can indicate changes or differences in relative workload before, or in the absence of, significant performance-level effects [3].

2.2.1 Cardiovascular activity

Basic cardiovascular measures (heart rate and blood pressure) have been shown to increase with escalating cognitive demand or workload in a range of environments [8-9]. Brookhuis and De Waard [9] reported that heart rate increased with heightened task demand, such as entering a traffic circle, and dropped as task demands decreased, for instance, driving on a two-lane highway. Thus, heart rate, the number of heart beats per unit time, usually per minute, was selected as a physiological measure to estimate cognitive workload complexity.

2.2.2 Electrodermal activity

Electrodermal activity (EDA) refers to the electrical changes in the skin and can be distinguished in tonic and phasic activity. Tonic EDA, the Electrodermal Level (EDL) or Skin Conduction Level (SCL), is the average level of EDA or baseline activity. Phasic EDA includes the Electrodermal Response (EDR), which is most similar to the formerly common measure Galvanic Skin Resistance (GSR). Mehler et al. suggested that skin conductance clearly documented a change in physiological arousal associated with the increasing complexity of auditory n-back tasks [3], although these findings are contrasted with the HASTE project findings, which found skin conductance is sensitive to increases in visual but not auditory secondary tasks during simulation [8].

2.3 Radial-basis Probabilistic Neural Network Models

Radial basis probabilistic neural networks (RBPNN) are applied for estimating driver's cognitive workload using driving performance and physiological measures. It is known that RBPNNs are suitable for classification problems such as cognitive workload complexity estimation. When an input is presented, the first layer computes distances from the input vector to the training input vectors, and produces a vector whose elements indicate how close the input is to a training input. The second layer sums these contributions for each class of inputs to produce as its net output a vector of probabilities. Finally, a complete transfer function on the output of the second layer picks the maximum of these probabilities, and produces a 1 for that class and a 0 for the other classes.

3. MODEL CONSTRUCTION

3.1 Data Source

3.1.1 Experimental setup

The experiment was conducted in the DGIST fixed-based driving simulator, which incorporated STISIM Drive™ software and a fixed car cab. The virtual roadway was displayed on a 2.5m by 2.5m wall-mounted screen at a resolution of 1024 x 768. Sensory feedback to the driver was also provided through auditory and kinetic channels. Distance, speed, steering, throttle, and braking inputs were captured at a nominal sampling rate of 30 Hz. Physiological data were collected using a MEDAC System/3 unit and NeuGraph™ software (NeuroDyne Medical Corp., Cambridge, MA). A display was installed on the screen beside the rear-view mirror to provide information about the elapsed time and the distance remaining in the drive.

3.1.2 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 [11] to establish reasonable cognitive capacity and situational awareness, and have not previously participated in a simulated driving study. The sample consisted of 15 males, who are in the 25-35 age range (M=27.9, SD=3.13).

3.1.3 Cognitive workload

An auditory delayed digit recall task was used to create periods of cognitive demand at three distinct 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 [11]. 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 stimuli 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.

3.1.4 Procedure

Following informed consent and completion of a pre-experimental questionnaire, participants received 10 minutes of driving experience and adaptation time in the simulator. The simulation was then stopped and participants were trained in the n-back task while remaining seated in the vehicle. N-back training continued until participants met minimum performance criteria. Performance on the n-back was subsequently assessed at each of the three demand levels with 2 minute breaks between each level. When the simulation was resumed, participants drove in good weather through 37km of straight highway. Minutes 5 through 7 were 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/recovery periods were provided before presenting instructions for the next task. Presentation order of the three levels of task difficulty was randomized across participants.

3.2 Model Characteristics and Training

3.2.1 Definition of cognitive workload

The cognitive workload was classified into four categories based on primary and secondary task complexity. The secondary tasks, so called n-back tasks, have three levels of difficulty. The 0-back task is a low-level cognitive challenge, but it is not particularly difficult and was not intended to be significantly stressful. The 1-back condition requires an additional step up in cognitive load in that the individual must both correctly recall from short-term memory the item presented previously as well as entering and holding the new item in memory. It was expected that the 1-back would have moderate impact on individuals. The 2-back form of the task requires highest cognitive load to recall from short-term memory within the n-back tasks.

3.2.2 Input features

Two driving performance measures, standard deviation of lane position (SDLP) and steering wheel reversal rate (SRR), and two physiological data, Heart Rate (HR) and Skin Conductance Level (SCL), were considered as input features to estimate the levels of driver's cognitive workload in the RBPNN models.

SDLP was calculated from 0.1 Hz high pass filtered lateral position data with removing lane changes using the AIDE project guidelines. SRR was calculated by counting the number of steering wheel reversal from the 2Hz low pass filtered steering wheel angle data per minute. For cognitive workload, the reversal angles, which have more than 0.1 degree of the gap size, were counted.

HR was converted from Inter-beat Interval (IBI) which was calculated after removing irregular distance between peaks, irregular peak form, and presence of low-frequency component in ECG using the Librow`s R-peaks detection algorithm (Librow^{TM}, Ukraine). 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.

3.2.3 Summarizing parameters

In this paper, window size was considered as the summarizing parameter for the inputs. Window size denotes the period over which performance and physiological data were averaged. The comparisons of window size could identify the appropriate length of data that can be summarized to reduce the noise of the input data without losing useful information. This paper considered three window sizes: 10, 20 and 30 seconds.

3.2.4 Model training and testing

Radial basis probabilistic neural networks (RBPNN) were used to construct the driver's cognitive workload estimation models. In this paper, the models were trained using the NEWPNN function in MATLAB. For training and testing RBPNN models, data of four task periods, which consist of a single task (driving only condition) and three dual tasks (n-back task condition), were used. A task was divided into multiple segments based on window size. For example, if the model uses 30s window, one task period divided into four segments as shown in Figure 1. In the same manner, 20s window set has six segments and 10s window set has twelve. In each task, half of the segments, i.e. two segments per subject in 30s window, were used for training and the other segments were used for testing. Thus, each neural net was trained and tested using different sets of measurements, i.e. 15x2, 15x3 and 15x6 examples for 30s, 20s and 10s window, respectively. Since the estimator is always evaluated on the data disjoint from the training data, the performance evaluated through the cross validation scheme correctly reflects the actual generalization capability of the derived estimator [6]. Model performance was evaluated with testing accuracy, which is the ratio of the number of instances correctly identified by the model to the total number of instances in the testing set.

4. RESULT AND DISCUSSION

The performance of the RBPNN models varies from the combined input features and window sizes. Among different combinations of inputs, i.e. SDLP, SRR, HR and SCL, the performance using SCL only and SCL and SDLP outperformed as shown in Table 1.

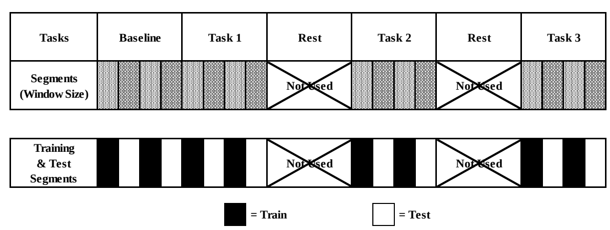

Figure 1. Allocation of Segments to Training and Testing Sets

Table 1. Model performance with different window size

		All	Driving Performance	Physiology		Driving & Physiology (Combination)			
				HR SCL	SCL	SDLP SCL	SDLP HR	SRR SCL	SRR HR
10s	Baseline	55.6	54.4	65.6	**94.4**	**86.7**	32.2	71.1	32.2
	0-Back	44.4	17.8	52.2	**74.4**	**70.0**	32.2	60.0	32.2
	1-Back	55.6	50.0	60.0	**84.4**	**86.7**	34.4	71.1	34.4
	2-Back	43.3	8.9	57.8	**82.2**	**90.0**	31.1	64.4	31.1
	Average	49.7	32.8	58.9	**83.9**	**83.3**	32.5	66.7	32.5
20s	Baseline	60.0	64.4	64.4	**93.3**	**91.1**	26.7	51.1	26.7
	0-Back	42.2	33.3	33.3	**80.0**	**73.3**	28.9	57.8	28.9
	1-Back	35.6	11.1	57.8	**86.7**	**86.7**	20.0	37.8	20.0
	2-Back	37.8	24.4	53.3	**82.2**	**91.1**	33.3	46.7	33.3
	Average	43.9	33.3	52.2	**85.6**	**85.6**	27.2	48.3	27.2
30s	Baseline	66.7	76.7	63.3	**90.0**	**90.0**	33.3	63.3	50.0
	0-Back	30.0	20.0	50.0	**80.0**	**70.0**	33.3	50.0	30.0
	1-Back	40.0	26.7	53.3	**83.3**	**86.7**	36.7	33.3	30.0
	2-Back	20.0	36.7	46.7	**86.7**	**90.0**	33.3	56.7	33.3
	Average	39.2	40.0	53.3	**85.0**	**84.2**	34.2	50.8	35.8

Due to the fact that skin conductance clearly changed in physiological arousal associated with the levels of cognitive load complexity, the best performance appeared when the models have SCL as an input feature. Although SCL model and SCL-SDLP model have same performance on average, SCL-SDLP model outperforms classifying the highest cognitive workload which must be detected correctly. The best performing model, which uses SDLP and SCL data over a 20s-window, could identify four graded levels of cognitive workload with an average accuracy of 85.6%. With this model, the estimation accuracy rate of driving only criteria, i.e. no cognitive workload condition, was 91.1%, and under cognitive workload criteria the accuracy of the lowest, moderate, and the most difficult cognitive load estimation were 73.3%, 86.7%, and 91.1%, respectively.

The results demonstrated that the model using SDLP and SCL was outperforming than the other combinations among performance and physiological measures. The main contributor of the high accuracy rate in this model was skin conductance level, which provides clear changes associated with difficult level of cognitive workload, but relatively lower threshold to distinguish higher mental workload. According to Mehler et al., the additional increases in skin conductance between the 1-back and 2-back were minimal and not statistically significant. The near flattening of the response curve for all physiological measures during the 1-back and 2-back tasks may indicate that a threshold had been reached relative to the amount of additional effort that participants were willing or able to invest in the combined demands of driving and the secondary cognitive task [6]. Thus, SCL and SDLP based model provides better performance to identify higher levels of mental demand than SCL based model.

5. CONCLUSION

In this paper, we proposed an algorithm for estimating driver's cognitive workload using driving performance and physiological data. Especially, SDLP and SRR, and HR and SCL were considered as cognitive load indices for the driving performance and physiological, respectively. In order to collect driving data, participants drove through highway in a driving simulator and were asked to complete three different levels of auditory recall tasks. The driver's cognitive workload estimation algorithm was developed using RBPNN models that were implemented by MATLAB NEWPNN function.

The results show that the proposed SCL-based or SCL and SDLP-based RBPNN models were able to identify driver's cognitive workload complexity with high accuracy. The model performance was assessed with the cross-validation scheme, which is widely adopted by the machine learning community. As a result, the highest workload estimation accuracy rate in overall model performance was 85.6%. And it is also expected that the accuracy can be improved by applying more sophisticated algorithms.

6. ACKNOWLEDGMENTS

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Speech, buttons or both? A comparative study of an in-car dialogue system

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ABSTRACT

In the DICO project a user test was performed to evaluate an in-vehicle dialogue system with three different modalities; speech user interface (SUI), graphical user interface (GUI) and multimodality (MM). Task performance, task completion time and driving ability were measured. We found that although the GUI was fast and easy to use, the participants experienced that their driving ability was better when using the SUI and multimodal interfaces, and the multimodal interface was preferred over GUI and SUI.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and presentation**]: User interfaces—*Evaluation*

General Terms

Design

Keywords

Evaluation, in-vehicle, dialogue system, performance, cognitive load.

1. INTRODUCTION

This paper describes an empirical investigation of an in-vehicle dialogue system comparing three different interaction modes (voice, manual and multimodal interaction) with respect to task performance, (self-estimated) driving ability and task completion time. In order to let the driver keep her hands on the steering wheel and the eyes on the road, dialogue systems are gaining an increasing interest from the car manufacturers. At the same time, the usage of mobile phones while driving is a much debated issue, for safety reasons. The main objection is that the mobile phone conversation takes the attention from the driving task, and the concern is that the usage of in-vehicle dialogue systems would show a similar pattern. However, since mobile phone conversations and dialogue system interactions are very different from each other, this type of comparison is not necessarily very meaningful. Furthermore, the alternative to dialogue system interaction is not no interaction, but interaction using manual (haptic) input and graphical output (as in traditional GUIs). To find out if a dialogue system is a reasonable alternative to manual input we therefore wanted to compare different user interfaces that is designed for performing the same tasks.

The overall conclusion is that the multimodal condition gives the same task performance as the manual condition, the same driving ability as voice condition, and beats both with respect to driving ability.

2. RELATED WORK

There has been a number of similar studies carried out before. For example, the SENECA project evaluated manual vs. speech input, when using a Driver Information System (DIS) containing radio, CD player, telephone and navigation [2]. 16 subjects compared a manual DIS system with a DIS system that was equipped with a speech input system. The findings from the study shows that a multimodal application is preferable, that safety can be improved by using speech, and that the drivers feel less distracted when using speech.

Another study, commissioned by Nuance and performed by the HMI laboratory of the Technical University of Brunswick, Germany [8], shows similar results. When comparing a manual interface to a speech interface, it was found that using a manual interface resulted in greater distraction and an increase in the number of times drivers looked away from the road. When using the manual interface the drivers rated their driving ability as poorer, and a Lane Change Task (LCT) showed a significant decrease in driving performance.

Medenica and Kun [5] compared interacting with a police radio using the existing manual interface to interacting using their Project54 speech interface, which was adapted to function in the same way as the manual interface. The graphical interface, unlike the SUI, resulted in a significant degradation in driving performance.

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However, all of the above mentioned studies compare two interaction modes, whereas the current study compares three: GUI, SUI and multimodal interaction. Furthermore, common to all earlier studies known to the present authors is the fact that the interactional capabilities offered in the evaluated modalities originate from different systems. Even if the systems have been adapted to make sure that they function in the same way, they are still different system. This makes it hard to determine exactly how they differ, and how much influence the design of the interfaces in the respective modalities has on the result. In general, it may be difficult to specify exactly what it means to say that a GUI and a SUI or multimodal interface function in the same way. We believe that the implementation of integrated multimodality (see below) in the DICO system used in the present study guarantees functional similarity in a principled way, while maintaining the advantages of the respective modalities.

3. BACKGROUND

3.1 The GoDiS dialogue system

The applications used in this study are developed using the dialogue system GoDiS [3]. GoDiS is implemented using TrindiKit [6]. General dialogue management issues such as feedback, grounding, question accommodation and task switching are handled by the application independent dialogue manager. Re-using these technologies in new applications enables rapid prototyping of advanced dialogue applications. GoDiS has been adapted to several different dialogue types, domains and languages.

3.2 The DICO project

The DICO project aimed to develop a proof-of-concept demo system, showing how a spoken dialogue system can be an aid for drivers. The Dico application was developed using GoDiS, and implements integrated multimodality. This means on the system output side that all modalities convey all information independently, without support from the other modalities. On the system input side, the user can freely choose either one of the possible input modalities at any time to interact with the dialogue system, since all modalities allow control of all functionality. The advantage of this approach is that the user does not have to rely on one single modality. If, for example, speech is unsuitable at the moment (e.g. due to a noisy environment) the user can choose another modality and still have access to all functionality. The user can also choose the modality that is most convenient for each action. It might, for example, be easier to speak a phone number instead of enter it manually on a keyboard while driving, and it might be easier to choose an item from a multi-choice list by pushing a button instead of speaking it.

For the study described in this paper we took advantage of the integrated approach and created three test conditions where the unwanted modality was temporarily removed:

1. SUI (Speech User Interface) interaction
   - speech only for input
   - speech and screen for output[1]
2. GUI (Graphical User Interface) interaction
   - buttons for input
   - screen for output
3. Multimodal interaction
   - speech and buttons for input
   - speech and screen for output

The Dico application contains a telephone domain and a domain for logistic tasks. When using the telephone domain it is possible to make phone calls by dialling a phone number or a contact in the phone book, and to add or delete a contact. The logistics domain is an aid for a commercial driver where it is possible to look at orders to find out where goods should be picked up, accept/reject orders, get information about driving time to find out when it is necessary to get a break, and to look at a map to see the route or to find out where nearby colleagues are located.

The setup of the keypad used for the manual input was similar to a computer keypad, see Figure 1. There were buttons for all figures, arrows to navigate up and down in a menu, an erase and an enter button and also preset buttons to choose domain (telephone or logistics).

Figure 1: Keypad used for manual input.

One area where the present study differs from previous work is in the use of the same dialogue manager for all three modalitity variants. The obvious advantage is that the results will not be affected by, for example, differences in the design of the menu structure or system instructions. To the authors knowledge, there are no previous evaluations of different interfaces using the same dialogue manager.

4. METHOD

There were ten subjects participating in the study, 6 females and 4 males, ages 27 to 53. None of them had any experience of controlling devices in the car using voice control or dialogue systems, although one of them had experience from using voice to control functions in a mobile phone.

The trials took place on a two-lane country road with several traffic lights and roundabouts. The traffic load was fairly moderate, with approximately 3 cars per minute encontered in the opposite lane. The participants drove a Volvo XC90 guided by the test leader along a predefined route. The entire route took about 30 minutes, which means that each test condition lasted about 10 minutes. There were four tasks to perform, two for each application:

[1] This means that the SUI output is not completely unimodal; the reason for this is that it was necessary to show a map on the screen to be able to perform one of the tasks.

- Telephone application
  - Call the contact “Staffan”
  - Add the contact “Elin” with home number “118118”
- Logistic application
  - Ask the system to read the first order
  - Show your colleagues on the map

The test leader planned the test so that the participants started each task at approximately the same spot along the route. We altered the test conditions so that one third of the participants began with the SUI condition, one third with the GUI condition and one third with the multimodal condition. This was done to minimize the bias from learning the system during the test so that the last condition is the easiest to use. Before starting the car, the test leader presented the tasks and demonstrated the first task (call the contact “Staffan”) by using the condition that the participant should start with. Before starting a new condition the participant was told to stop the car so that the test leader could demonstrate that condition. The participants also practised the task while the car was standing still.

5. RESULTS

We wanted to compare ease of use and how the driving ability changed depending on modality. Task performance was measured by the test leader on a 4-grade scale:

- Ok without support
  - the task was performed without any help from the test leader
- Ok with light support
  - the test leader gave one or two instructions
- Ok with considerable support
  - the test leader gave three or more instructions
- Not ok, task is aborted
  - the test leader or the participant decided to abort the task
- Ok with slight mistake
  - the task was performed, although there were a slight misunderstanding of the task. For example, the participant added the wrong phone number or called wrong contact. In these cases, the mistakes were due to wrong input from the participant and not a misinterpretation from the system.

Driving ability was estimated by the participants. After each task, the participant was asked to estimate the driving ability during the task on a 10-grade Likert scale, where 10 meant “My driving ability was equally good as when I drove without performing any task” and 1 meant “My driving ability was really bad”.

We also measured task completion time for each task, starting with the participant pushing the first button to either start the voice recognition or choose menu on the manual interface, and ending with the participant returning to the main menu.

5.1 Task performance

Figure 5.1 shows task performance.

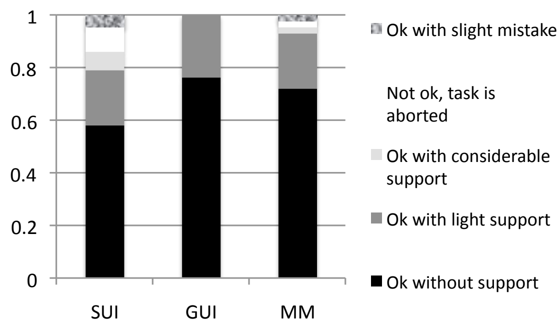

Figure 2: Task performance.

When using the manual interface, the participants did not need much help from the test leader, and the tasks were performed with no or only slight support.

When using the speech interface, the majority of the tasks were performed with no or only slight support from the test leader, or was performed ok but with a slight mistake. Approximately 20% of the tasks needed more support or was aborted. In the cases where the task was aborted, all in all three times, it was due to the system not being able to perceive the input or misinterpreting the input.

Multimodal interaction was similar to GUI interaction, although a few tasks needed considerable support, or were ok but with a slight mistake. In one case the task was aborted; this was due to the user using an expression that was not covered by the lexicon. Instead of using the keypad, the user chose to abort and then restart the task and was able to perform it using another expression.

5.2 Self-estimated driving ability

Table 1 shows self-estimated driving ability.

Modality	SUI	Multimodal	GUI
Mean	7,5	7,25	5,48
STD	1,90	1,76	1,91
Median	8	7,5	6

Table 1: Estimated driving ability according to the drivers.

The participants estimated their driving ability higher when using the SUI or the multimodal interface, compared to the GUI interface. A one-way Anova test shows that the difference between the GUI compared to the SUI and the multimodal interfaces is statistically significant, $F(2,113)=12,923$, $p<0.01$. There was no significant difference between the SUI and the multimodal interface.

We also wanted to know if there were any bias from the learning effect that influenced how the drivers scored their driving ability. Since all drivers were used to use keypads on their cell phones and computers, it might be easier for them to understand the manual interface than the speech interface which they were not familiar with. Therefore, we looked at how they rated their driving ability after the first session using the first interface, and then at their ratings after the last session when they have tested all interfaces. The hypothesis was that the ratings after the first session would be in favor of the manual interface, and that that would change after the third session when the drivers were more familiar with the dialogue manager.

However, Table 2 shows that after the first session the drivers rated their driving ability highest when using the SUI and lowest when using the GUI.

Modality	SUI	Multimodal	GUI
Mean	6,9	6,9	5,5
STD	2,16	1,1	2,3
Median	7,5	7	5,5

Table 2: Estimated driving ability after the first session.

When starting the third, and last, session, the drivers had become somewhat familiar with the dialogue manager and knew what information the system wanted to have. Table 3 shows the ratings after this session:

Modality	SUI	Multimodal	GUI
Mean	8	7,5	6,6
STD	2,1	1,9	1,4
Median	8,5	8	7

Table 3: Estimated driving ability after the last session.

Tables 2 and 3 indicate that there is a learning effect, since the drivers' ratings are on average higher after the last session compared to the first. We may note that the relative position among the interfaces remains the same.

5.3 Task completion time

Table 4 shows average task completion time.

Task completion time was longest when using the SUI interface, when using the GUI interface the tasks were performed in half the time. A one-way Anova test shows that the lower task completion time when using the GUI interface compared to the SUI and multimodal interfaces is statistically significant, $F(2,112)=6,296$, $p<0.01$. There was no significant difference between the SUI and multimodal interfaces.

Modality	SUI	Multimodal	GUI
Mean time (seconds)	70	61	37
Highest	194	171	84
Lowest	20	9	13

Table 4: Task completion time in seconds.

6. DISCUSSION

One thing the test leader noted was that four of the participants did not start the task immediatly when using the GUI, but took the opportunity to perform the task while standing still at a traffic light. When using the speech and multimodal interfaces only one of the participants performed one of the tasks while standing still. Several of the participants complained that the graphical interface took attention from the driving since they had to look at the screen. One of them scored the driving ability to 3 although he was standing still waiting for the traffic light to turn green, since he felt that he was so occupied by the interaction that he forgot to look at the traffic light. This might of course be due to a bad interface design, but when asked the participants felt that the interface was easy and intuitive. Therefore, it is interresting to see that although the GUI interaction was the fastest - task completion time was halved compared to the SUI and multimodal interactions (see Table 4) - the participants found it most distracting and that their driving ability was worst during this condition (see Table 1). We might draw the conclusion that to feel in control of the driving it is better to be partly occupied during a longer period of time, than almost fully occupied during a short amount of time.

The main reason why the SUI and multimodal interfaces were slow was due to turn-taking problems caused by the speech recognizer and the way it was connected to the dialogue manager. System response time has been considerably improved since this study, but further improvements would be beneficial, both regarding reducing word recognition errors and process time, in order to be a competitive alternative to GUI interaction.

None of the tasks performed while using the GUI were classified as "Ok with slight mistake". The test leader noted that the reason for mistakes in the VUI and multimodal interactions was not due to word recognition errors, but instead the participants actually misunderstood and said, for example, a wrong phone number. It remains to be answered why this happened only when using the speech or multimodal interfaces, but never when using the GUI. One reason might simply be that the interaction, as mentioned, was faster when using GUI and therefore they could remember the correct thing to say.

None of the participants needed any support while using the GUI, as opposed to when using the other interfaces. It remains to be investigated whether it depended on the interface being easier to use, or perhaps was due to the fact that none of the participants had used a spoken dialogue system before. Maybe they would have needed longer time to get used to the interface than they needed to learn the GUI which was similar to what they had used before. None of the participants aborted a task using the GUI interface, although three participants aborted a task using the SUI interface. The reason was that the system could not hear or misinterpreted what the user was saying. This can be used as an argument in favor for the multimodal interface, since the participants in these cases could have switched to manual input if that options would have been available. To further improve the interaction, the system should be adaptive when it comes to learning new expressions so that the user can use her preferred expression next time instead of using the default expression or give the input manually.

[8] states that voice operation of in-vehicle information systems (IVIS) is desirable from the point of view of safety and acceptance. The study reported in this paper supports that, but we recommend a multimodal interface. Although the drivers, when asked, preferred to interact using speech, a manual alternative is useful when a speech interface is not wanted. For example, if the environment is noisy, the driver does not want to disturb the passengers or the speech recognizer does not seem to understand what the driver is saying. When it is not possible or appropriate to use speech, a multimodal interface gives the driver an opportunity to choose.

7. SUMMARY AND CONCLUSIONS

To sum up:

- Regarding task performance, SUI gets the lowest scores whereas MM and GUI get roughly similar scores
- Regarding driving ability, GUI gets the lowest score, whereas MM and SUI get roughly similar scores
- Regarding task completion time, GUI is the fastest whereas MM and SUI get roughly similar scores

The MM condition gives the same task performance as GUI, the same driving ability as VUI, and beats both with respect to driving ability. Future research includes improving the MM system to decrease task completion time, and investigating whether (and how) this affects driving ability.

8. FUTURE RESEARCH

Since the study reported here was conducted, the multimodal Dico application has been extended with a *speech cursor* [4]. The speech cursor enables the user to use spoken interaction in combination with haptic input to access all functionality (including browsing long lists) without ever having to look at the screen. It requires a haptic manu navigation device, such as a mouse (trackball, touch pad, TrackPoint^{TM}) with buttons, pointers and drivers, keyboard with arrow keys or jog dial/shuttle wheel. A typical in-vehicle menu navigation device consists of three or four buttons (UP, DOWN, OK and possibly also BACK). Every time a new item gets focus, the system reads out a "voice icon" - a spoken representation of the item. This representation can be textual, intended to be realised using a TTS, or in the form of audio data, to be played directly. Every time a new element gets focus, all any ongoing voice output is interrupted by the "voice icon" for the element in focus. This means that you can speed up the interaction by browsing to a new element before the system has read out the previous one. In future work, we plan to perform a study comparing a multimodal system with speech cursor to voice-only, GUI-only, and multimodal interaction without speech cursor.

Additional future research includes implementation of theories of interruption and resumption strategies. In-vehicle dialogue involves multitasking. The driver must be able to switch between tasks such as, for example, adding songs to a playlist while getting help to find the way from a navigation system. To avoid increasing the cognitive load of the driver, the system needs to know when it is appropriate to interrupt the current dialogue to give time-critical information [1]. When resuming the interrupted dialogue, the system should resume when the driver is prepared to do so and in a way that does not increase the cognitive load [7].

9. ACKNOWLEDGEMENTS

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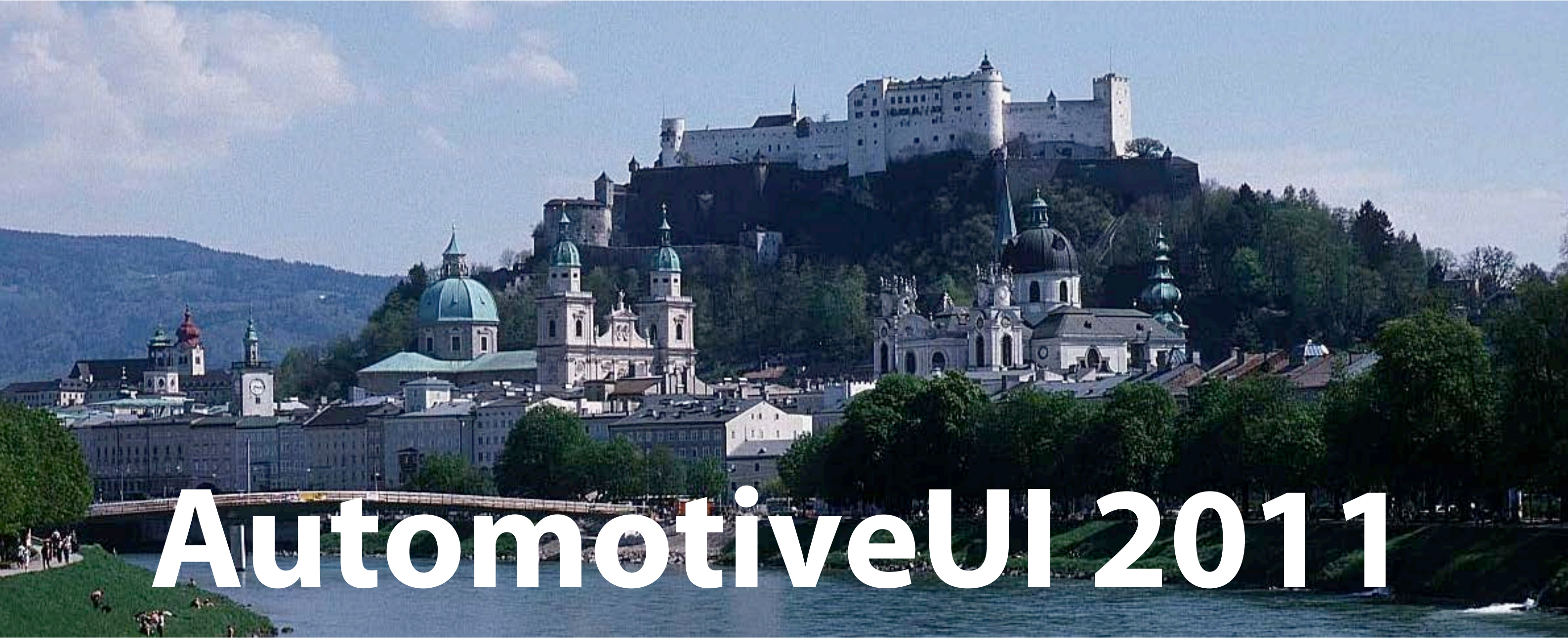

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ADJUNCT PROCEEDINGS
WORKSHOP "AUTONUI: AUTOMOTIVE NATURAL USER INTERFACES"

Workshop Organizers:

Bastian Pfleging	VIS, University of Stuttgart
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From Tangible Bits to Seamful Designs: Learnings from HCI Research

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ABSTRACT
In this two-page position paper we draw attention to a few design concepts and learnings from the HCI community that we find important for car researchers to learn from when now entering the design space of gestures and movement-based interaction in the car.

Keywords
Tangible Bits, Gestures, Movement-Based Interaction, Seamful Designs, Materiality and Interdisciplinary Design.

INTRODUCTION

As the call for this workshop states, natural user interfaces (NUIs) by means of gesture and speech interaction is becoming an important topic in car related research as well as already for products related to infotainment and entertainment. In HCI, tangibility, gestures and movement-based interaction have received great attention for at least the last fifteen years, since Ishii and Ullmer introduced their notion of Tangible Bits in 1997 [5]. We therefore for this workshop want to direct attention to a few of the advances and issues on these matters from the HCI community in general. We bring attention to Benford and colleagues' framework on Sensing-Based Interaction [1], Chalmers and MacColl's argumentation for seamful designs [4], as well as the coming research trends in HCI concerning Materiality and Interdisciplinary Design.

FROM TANGIBILE BITS TO FREE MOVING GESTURES

Ishii and Ullmer were groundbreaking when they in 1997 introduced their concept of Tangible Bits [5]. What Ishii and Ullmer suggested was to make the background happenings of a computer system more understandable to its users by connecting the underlying "bits"/happenings to physical objects the user could interact with and thereby come to understand how these underlying events were connected to each other in the interaction. From tangible designs, but also on its own, systems using free moving gestures developed, from systems using simply hand gestures [6] to systems using full body movements, as in dancing interaction for example [3]. Today we even see more and more commercial systems letting users interact with their whole body freely in space, e.g. the Kinect system.

A slightly forgotten issue though when leaving the specifics of button pressing for more free physical interaction, is the notion of what aspects of those body movements or gestures a system need/should pick up upon in order to fulfill a desired user experience. Is it really the specific gesture as such a system needs to know of in order to make the internal decisions for what feedback to return to the user, or is it the overall shape or size of the gestures that are needed, or the effort required or the intensity or perhaps it is some other aspect of the movements that is required? There is a brilliant paper by Benford and colleagues discussing these issues of connecting the users' expectations of a system with what the system is/can be sensing in order to fulfill what is desired of a specific system design [1]. To capture the complete picture of some movements is, if not impossible, but very hard to accomplish. Since it most often is not the complete picture that is needed there should be thorough discussions on these matters in the interdisciplinary design team, so that the designer not has one thing in mind and the engineer another and also so that not time is wasted trying to accomplish something that actually is not needed to allow for some desired user experience.

FROM SEAMLESSNESS TO SEAMFULNESS

In order to track some characteristic or some characteristics of free moving gestures there is today a range of new sensor technologies, such as accelerometers, RFID tags, NFC, various other radio technologies, such as WiFi or Bluetooth, and in the car also various camera technologies can be possible.

When these technologies first became possible for designers to work with it was the ubiquitous society we were talking of, a world where every thing and every user would be smoothly connected and the user would be able to interact with anything, anywhere without having to think about it. That world never really happened, instead we found ourselves both as designers and users struggling with being connected and understanding why we, or some equipment we had, were not connected all the time (that more or less until now). And even though being connected now in many ways can be said to be a resolved problem, and that perhaps especially in the car, Chalmers and MacColl's spot on argumentation for seamful designs [4] in opposition to this dream of seamlessness is still relevant, and that perhaps especially in the car that nowadays is more and more of a locked computer system to its' everyday driver/user. What Chalmers and MacColl meant with seamful designs was that the functionality and the internal connections between various parts of a system would be understandable to users in how they were connected and in some sense why. Very much similar to what Ishii and Ullmer wanted with their tangible bits, to make the internal structure of some system more understandable to its users so that they if not could help their system connect by moving the GPS system closer to the window or similarly, but at least understand why the system at some point in time was not working as it should.

All this again becomes highly relevant when we now as interaction systems designers enter the world of wireless sensor technologies, in the car, and elsewhere.

FROM BITS TO MATERIALITY

Another issue we have though when now entering this "new" world of digital materials, i.e. mobile sensor technologies, is that the digital, hardware and software, always has been, but now even more, a very complicated design material for many designers to work with. As any other designer, such as textile designers or artists, interaction systems designers should be able to handle and play around with their design material, in their case the digital, while working out a design in order to make use of all the potentials that comes with this brilliant material of digital technologies. At the same time though, it is very rarely that we see someone perfectly skilled in creative design and hardcore engineering, all embodied into one person alone. More and more common in HCI are therefore interdisciplinary design teams, where dancers, psychologists, behavioral scientists and others work together with creative designers and engineers developing a specific design solution together. As HCI experts we can only guess that the same goes for design teams involved in car development. As it is not possible to touch or feel digital materials at any given moment, understanding properties and potentials of digital materials is a major challenge for design teams and management. Methods and tools are needed that enable these interdisciplinary design teams to work with digital materials as a shared resource within design innovation. The novel Inspirational Bits approach [7] is one such method. In this method the engineers in parallel with the designers conceptual work develop quick and dirty designs in materials that appear likely to be used. This they do for two reasons, first to allow themselves to get an understanding of the design materials at hand and their interactional material properties that cannot be felt and thereby not completely understandable if not set together into a running system. But also they do this in order to become able to communicate these properties in a fun, inspiring and understandable way to the rest of the design team, for everyone to become able to use the material properties as inspiration for the design they develop together. This we find would be a very interesting method to use in the very technically advanced material context of the car.

CONCLUSION

To conclude, this rough walk through of some of the issues concerning the development of gesture and movement-based interaction in HCI we want to state that the car is a limited physical space and as researchers and designers in this design space we need to be very sensitive to the issues of safety and driving. But with that in mind there are great possibilities here for what more "natural" user interfaces involving gestures and speech can do towards reducing driver distraction in certain cases but also towards services that allow for new bodily experiences in the car. Of course we do not see a future where the driver or the passengers will be dancing in cars, but we do see a future with more bodily experiences in the car, such as the bodily experiences of singing out load or the bodily experiences of backseat gaming [2]. But we also see how the HCI community in general has perhaps a longer history of discussing issues of movement-based interaction, bodily experiences and material possibilities, which is why we with this position paper hope to draw attention to some of these issues for the car research field now to build further upon, and build on from all the great possibilities of the specifics of the digital materials in the car.

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AutoNUI dilemma: to drive or not to drive?

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ABSTRACT
In this paper, we briefly describe our position and our recent activities in the domain of automotive interfaces and natural user interfaces, distinguishing between UI directly related driving tasks and UI devoted to other tasks.

Keywords
Automotive, NUI, natural user interfaces, driving.

DEFINITION OF NATURAL USER INTERFACES

In literature [1] [2], natural user interfaces (NUIs) refer to UIs that are effectively invisible, or become invisible with few learned interactions to its users. NUIs rely on a user being able to quickly evolve from novice to expert. The learning is typically easy and fast because users have to execute relatively natural motions, movements or gestures that they quickly discover how to control the application or manipulate the on-screen content. Not necessarily NUIs are mimicries of nature or of already existing gestures 'outside' the UIs. The aim is to obtain an interface that can be perceived by users as 'natural', that means in other words: (1) **self-consistent**, or with a strong and direct relationship with actions, effects and feedbacks made available through the interface itself; (2) **unobtrusive**, or seamlessly integrated with other users' actions and perceptions in the same environment and at the same time; (3) **not artificial**, or not acted through commands hard to understand, learn, recall.

TWO AREAS OF INVESTIGATION

We identify at least two main areas for automotive UI:

(A) the area strictly related to the task of driving,

(B) the area NOT strictly related to the task of driving.

UI FOR DRIVING

In the former, we can identify systems and controls at three different layers: (A1) directly related with **basic driving tasks** (like steering wheels, pedals, shift levers, etc.); (A2) controlling driving **assistive systems** (to set parameters for traction controls, shock absorbers, brakes controls, etc.); (A3) supporting and enhancing **drivers' reactions and behaviors** (in real-time, like in distraction-detection systems, or in the long period, like in eco-drive supporting systems).

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UI NOT FOR DRIVING

In the latter, we can further consider several UIs for some domain-specific areas: (B1) in-car **entertainment** (CD and MP3 players, multimedia systems for backseats, etc.) , (B2) in-car **environment** (air conditioning, lights controls, seats positioning, etc.), (B3) **integration with personal devices** (mobile phones, consoles, tablets, etc.) , (B4) **integration with networks and services** (communication networks, social networks, meteo and traffic services, etc.).

OUR ACTIVITIES

We are involved in a team with industry partners, currently working (1) in a funded applied-research project and (2) in the proposal writing for a second one, currently under evaluation. The project currently on going is focused on the area (A) of automotive UI, while the one under evaluation is on the area (B). In the next paragraphs we summarize the research topics being addressed by the two projects.

NUI FOR ENHANCING DRIVERS PERFORMANCE

Between setting up systems that can substitute drivers in controlling some aspects of the car behavior (A2) and being part of systems that can measure and support drivers' behaviors (A3), a current trend is to design systems being able to enhance drivers' perception, but leaving to themselves the control of the car. Good examples of those systems are iOnRoad by picitub [3] and Augmented Driving by imaGinyze [4]. Interacting with a system that is enhancing your personal senses should be obviously (and better) done through natural user interfaces. One possible approach, a part the examples given, that are using mobile devices as both application platform and user interface, is using the whole windscreen as the place where to project information with simple feedbacks and actions performed through simple gestures.

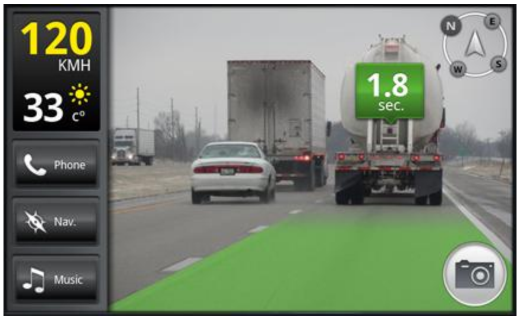

Figure 1 - the iOnRoad user interface [3]

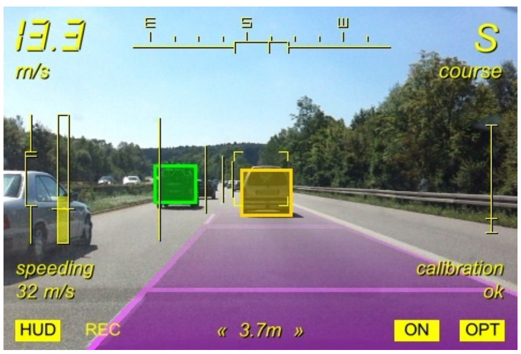

Figure 2 – Augmented Driving user interface [4]

Examples in this direction are: the next generation of HUD by Pioneeer [5], eyeSight by UNIVO [6], and eViacam [7].

Figure 3 -Pioneer HUD prototype [5]

UI FOR SOCIAL SERVICES IN THE CAR DOMAIN

Between (B3) and (B4) there is room to investigate for how to implement the key elements of social service (community, conversations, identity) [6] within the automotive domain. As an example, we can design and implement “conversations” within a community of a social service thinking about two phases [8]: the listening phase and the speaking phase.

In the speaking phase, social services allow users to display personalized content, their social context and their activity: this can be done sharing content, updating a status, using the ‘Like’ button, commenting others’ content, etc. Translating these activities into natural, unobtrusive actions and gestures within the in-car environment and domain can be a hard challenge, also considering the design constrains in the automotive industry.

Figure 4 - eyeSight demo [6]

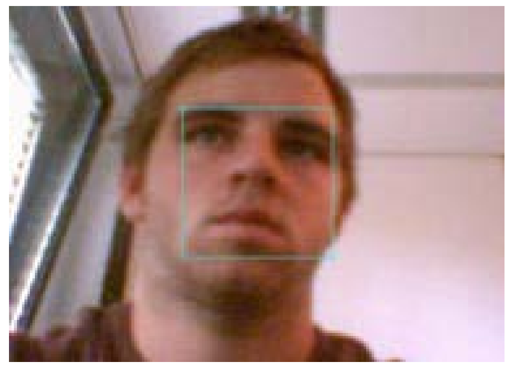

Figure 5 - eViacam demo [7]

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Designing Driver-centric Natural Voice User Interfaces

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ABSTRACT
The current growth of automotive electronics aims to extend vehicle functionality and information access. This paper explores the application of Natural Voice User Interfaces as a preferred interaction modality with in-vehicle technologies to lower driver distraction effects and improve the user experience. The benefits and risks of natural speech interactions are evaluated in order to propose a driver-centric design guideline based on previous research. The paper concludes that driving scenarios can profit considerably from systems that apply natural speech interfaces to allow the driver to access information.

Keywords
NVUI, natural speech, driver-centric design, cognitive load, in-vehicle interfaces

INTRODUCTION
The exponential increase of vehicle electronics nowadays presents a challenging microcosm for human computer interaction. As most of the technology in the car becomes digital, automobiles are turning into interactive spaces where human factors play a crucial role in the design and resulting user experience [1]. In-vehicle technologies are implemented not only to assist with vehicle operation but also as a gateway for information access, media consumption and entertainment. However, any vehicular system that requires interaction with the driver or other passenger(s) has to account for safety and driver distraction effects.

Natural User Interfaces are becoming the preferred choice when looking at reducing the cognitive load of in-vehicle systems. The use of auditory interfaces, that are eyes-free and hands-free, is strongly supported when the interaction design focuses on the driver, as demonstrated when analyzing the effects of modality in dual-task performance for driving scenarios [2, 3].

This paper explores the use of Natural Voice User Interfaces (NVUI) in driving scenarios, analyzes its risks and benefits and aims to propose design guidelines for driver-centric applications based on previous research experience.

NVUI APPLICATION IN AUTOMOTIVE ENVIRONMENTS
A natural voice user interface (NVUI) is one in which a person can speak to a computer system as they would when conversing with another human being. NVUIs are agent-based systems that understand what the user says and respond to it [4]; therefore, allowing users to interact in a natural way eliminating the need for remembering a specific lists of commands.

Automakers and Original Equipment Manufacturers (OEMs) have traditionally opted for command-based voice user interfaces in the implementation of vehicle systems, driven by the higher speech recognition rates that result in a limited list of terms. However, as functionality increases, so does the probability for a Word Error Recognition (WER). Furthermore, command-based interfaces can become unfriendly and underused as the list of available commands grows.

Some of the current NVUIs make use of rich grammars that have significantly enhanced recognition by looking for particular responses from the user in different contexts of the interaction [5]. Both users and NVUI developers know that there is much room for improvement in this area [6]. In NVUIs a reduced number of responses available to the user results in a better recognition The natural language expected by a system can be from a minimum amount of words to a large vocabulary, which could essentially understand free form input [4] depending on the size of the grammar corpus.

BENEFITS AND RISKS OF NVUI IN VEHICLES
Natural voice user interfaces offer many benefits when integrated with automotive technology. While society has become accustomed to facile machines using command-based actions, natural voice user interfaces offer users a decreased cognitive load and natural interaction. The use of natural conversational language minimizes the amount of training necessary to interact with a system; often times being safer and more advantageous than locating buttons or

keys to press on a visual display. Mobile devices are a growing cause of driver distraction where NVUIs can provide an invaluable method of interaction for many. Just like a conversation with a riding companion, interactions with a natural voice interface flow reducing the necessity to look away from the road. Additionally, they can also serve the needs of disabled users who are many times disenfranchised by automotive designs and must enlist customizations to effectively use their vehicles.

Despite the fact that there are many advantages to natural voice designs there are many risks that designers find outweigh the benefits. "We find speech interaction with simple machines to be interesting because it sidesteps the artificial intelligence problems of natural language in favor of the ubiquitous nature of speech interaction" [6]. In order to facilitate the natural aspects of conversation, designers and developers alike find themselves having to understand the inner workings of language in general. While it can be difficult for a human to understand and recognize all the different ways to say things, it becomes that much more difficult to teach a computer to do so. Notwithstanding, homonymic and slang phrases can become increasingly difficult to process, especially depending on the region and dialect of the designer. Increased attention to the potential complexity of conversational models can detract from functional design and decrease user satisfaction with the system. In contrast, a well-designed interface can create a false sense of comfort and foster an environment where a driver then thinks they can manage other tasks at the same time.

Overall, natural voice user interfaces can be useful in automotive design; as manufacturers increase the technical functionalities within cars the cognitive overload of drivers will be increased. The role of natural voice interfaces can greatly impact those functionalities, but only under the appropriate design principles.

NVUI DESIGN PRINCIPLES FOR DRIVING SCENARIOS

Hua and Ng noticed the lack of systematic guidelines to design voice user interfaces that reduce negative impact on drivers [7]. Addressing NVUI challenges for creating safe and natural applications requires analysis and creativity, and is dependent upon the purpose for which an application was created.

Human vs. Synthetic speech

The first of these issues is the decision of implementing human speech vs. synthetic speech [8]. Human speech refers to speech segments that are prerecorded by a human while synthesized speech is an artificial production of speech via a computer, and is often produced via text-to speech (TTS) engines.

Utilizing natural speech, in comparison with synthetic speech, in applications that deliver high amounts of prerecorded speech segments is found to be difficult and rather costly [9]. Some applications require speech outputs that are dynamic to the content they present; such as email headers and email content [10]. To deliver such output through human speech requires a person to record necessary prompts whenever needed without delay. Such an approach is in most cases unfeasible, even during the prototype phase where the developing process of the application often obliges to redesign prompts. With the rapid development and implementation of vehicular voice-activated applications, developers commonly tend to use TTS for the flexibility in presenting dynamic content.

When designing voice activated applications using synthetic speech, it is important to take into consideration the deficits that such utility may endure. TTS continues to have various shortcomings. Despite the constant improvements on synthetic speech quality, it is still considered hard to comprehend in comparison with natural speech [11].

Some of the deficits noticed in synthetic speech are the lack of tone fluctuation and omitted pauses between words, which make speaking styles harder to understand. Despite that, using synthesized speech gives the developer better control over speech parameters.

Likewise, NVUIs tend to produce in the users a phenomenon that Watts named habitability [12].When a system shows an advanced degree of natural language understanding, users tend to confer it human-like abilities. Failure to meet those expectations ends in dissatisfaction and lower user acceptance. The use of TTS is a clear indication to users that the system, however advanced, is still a machine, leading users to lower their expectations and therefore raising their feel of control.

Output design

Regardless of the form of speech chosen by the developer, it is vital to a voice-activated application that voice outputs are understandable. This is of crucial importance for automotive environments where the interaction with the NVUI is generally a secondary task. Prompts should be designed in short and clear segments that require less cognitive processing. The amount of auditory information that a person can process is different for every individual and also depends on the amount of attention that s/he can direct to the system, which in many cases depends on the road conditions. Research suggests that auditory information pieces should be kept short, better not exceeding one-minute in length, to ensure participants understanding and focus on the road [13].

Barge-in

Another issue that arises when designing NVUIs is the decision to allow for barge-in. While prompted by the applications, many users demonstrated signs of dissatisfaction and frustration when they sense the system's control over their interaction, preventing them from speeding up the navigation process. Barge-in is a feature that allows a user to interrupt a prompt in means to navigate to the next prompt, speeding the interaction. The difficulty with enabling this feature arises when the user's incoming speech becomes corrupted with echo from the ongoing prompt, thus affecting the recognition [14]. The latter causes frustration and ultimately dissatisfaction with the application. Designers should evaluate whether to risk false inputs, given the noisy atmosphere of the driving environment, or to restrict user's control of the interaction. Different parts of the interaction dialogue can benefit from applying barge-in.

Dialogue design methodology

According to Tomco et al, command-and-control dialog is the simplest dialogue methodology where a user is limited to a strict vocabulary of specialized commands [14]. This method retains low WER rates, but is found to be difficult to use, as learned skills cannot be applied to other voice applications. Thus each system presents a steep learning curve. In particular, command-based applications can pose a disadvantage when users accustomed to them use natural speech systems. The directed dialog method helps navigate the user through the application prompts following a certain path, collecting pieces of information along the way before they could reach their goal. This design poses low flexibility possibly causing an element of frustration in the user. On the other hand, natural language dialog allows the user to direct the system to the information they are seeking by simply posing complex conversational queries the same way they would approach a human being. Presenting the most natural way of communication, this method is harder to implement.

Capturing the user's mental model

Users are often unclear of how to obtain certain information from an application. A developer using natural language design needs to account for various ways of capturing and analyzing user's input, outputting the correct information back to the user. Designing a product that will repeatedly create positive user experiences is essential for sustainability.

When developing vehicular smart NVUIs, drivers' trust should definitely be taken into consideration; trust being a direct result of positive or negative experiences. When users lack trust in automated systems they will probably underutilize or disuse them [15]. Therefore, a system should allow for trust calibrations as well as an increase in the user's acceptance of the system [16]. An iterative development approach is most needed in the application of NVUIs to automotive environment.

Positive user experiments are results of designing systems that understand drivers and their motives. Evoking pleasant emotions can add to the user's experience. One key component to consider when designing a NVUI is desirability, which is a combination of utility, usability and *pleasurability* [17]. Vehicle owners are interested in systems that add to their safety, while still addressing their needs.

Designing for user experience

A product experience approach is able to yield groundbreaking innovations, because it does not start out from existing products, but it takes the user needs, emotions and expectations as a starting point [18]. Vehicular NVUIs should follow Human-Centered Design principles, which emphasize not developing a system "around" the user but a user-product system instead [19].

CONCLUSION

User Experience research suggests that driving environments can benefit greatly from systems that apply natural speech interfaces to allow information access for the driver. NVUIs provide the lowest cognitive load and highest user satisfaction among different modalities, especially under high workload scenarios. There are nonetheless, certain risks that still have to be addressed, as NVUIs do not report the same successful results for every participant. Independently from typical speech recognitions issues, like slang terminology or strong local accents, users with long time exposure to command-based voice applications can present adaptation problems to natural speech input and potentially show lower satisfaction rates.

However, thanks to the interaction with consumer electronics like smartphones that make use of NVUIs for hands-free interactions, society will grow in familiarity with natural speech interfaces and these issues are expected to decrease over time. Furthermore, prolonged user interaction with NVUI systems will provide enough training data for Artificial Intelligent Systems to adapt to the user, increasing speech recognition accuracy.

Finally, designers must account for context-awareness in the implementation of their system interactions. In automotive applications this context-awareness can be applied following two approaches. On one hand, awareness focused on the user, where understanding his/her stress level, frustration or mood can determine the way the system reacts or presents information. On the other hand, context-awareness resulting from the interaction of the NVUI system with the vehicle's on-board computer or other electronic systems in the car, can help determine the amount of attention the user can procure and therefore modify the way information should be presented.

NVUIs can thus potentially open the gates to information accessibility in highly complex scenarios like driving.

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Using the last steps – exploring natural interaction for automotive use cases

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ABSTRACT
Adjusting the car to the drivers' and passengers' needs is a key value for safety, well-being and customer satisfaction. Configuring the car can be tiresome and complex. Methods of pre-configuring may raise the level of comfort if applied correctly. We introduce several scenarios to use the time of approaching the car for implicit and explicit communication between human and machine by 3D object recognition and gesture interaction. Identifying persons and understanding their situation is critical to set gestures into the right context. First steps towards assembling a prototype to explore the range of natural interactions around the car have been taken to test the feasibility of the approach.

Keywords
Gestures, implicit interaction, remote control, visual context sensing, privacy settings, configuration, pre-configuration, optical sensor.

MOTIVATION
Paul likes to listen to loud metal music while driving. He has a date tonight he is looking forward to and happily drives to the restaurant where they want to meet. The evening goes well, and Paul offers to drive his date home. They go to his car, and while walking towards it, several things happen: As it is a cold evening and they walk towards the car together, seat heating is switched on for both front seats. Moreover, Paul performs an unobtrusive gesture with his right hand, which is a secret sign for his car to switch to quiet romantic music to avoid the embarrassing moment of screaming load music when starting the car. They both enter the car and Paul is pleased about his intelligent car when he notices that his date is feeling well.

APPROACH AND METHODOLOGY
The idea is to use data available even before driver and co-driver are sitting inside the car. Everything the driver or the car itself do before actually entering the vehicle shortens the time needed to start driving. Moreover, if you get the impression your car understands the context of approaching and supports your needs and wishes, the relationship between driver and car will become more natural as the technical and therefore impersonal pressing of buttons or choosing settings in a menu can be omitted. Today, a bidirectional communication between car and key can be established in a range between 15-20 meters around the car. This enables us to activate the sensors several seconds before the car gets unlocked. This additional time is very valuable to apply configurations and settings and prepare the car.

Figure 1: Differing approaching scenarios.

Using sensor data
On the one hand, adjustment can happen implicitly – like recognizing the amount of people walking towards the car, or how tall they are so the car can be prepared for the expected passengers. Fischer et al. [1] have developed a support system for cars where an omnidirectional vision sensor detects an approaching person as well as height and size characteristics. By additionally building up a model of the surrounding, doors are automatically opened without collisions in narrow parking situations and the seat position is preset to allow for comfortable ingress. We aim to enhance this approach to further improve context sensitivity. On the sensor side, integrating techniques like face detection and additional sensors can be used to enrich available information. On the application side, this knowledge can be used to support more than the ingress process. Different scenarios are possible, like unlocking the trunk when sensing a large carried along object, switching on seat heating depending on number of persons and temperature, using identification data to load specific music playlists, or setting privacy contexts.

Defining explicit communication gestures

On the other hand, explicit gestures offer potential for preparing the car while approaching. 3D gestures operated on hand or arm level can be used to communicate unobtrusively during the last meters, and allow making adjustments like opening the roof of a convertible without searching for the key. In another scenario, gestures can be used to set the privacy level of the infotainment system, like hiding navigation history or media consumption details when certain persons are accompanying.

FUTURE STEPS

At the moment we are using the RGB and depth image of a Microsoft Kinect© and the OpenNI framework to create skeleton models for the detection of gestures. In combination with face and finger recognition algorithms based on eigenface detection [2] and background subtraction [3], a broad range of sensor data is available. Future steps include finding the ideal position to attach cameras to allow for distortion-free taking of images. Furthermore, evaluation methods to test the benefit and acceptance of pre-adjustment while approaching need to be developed.

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Augmenting Future In-Vehicle Interactions With Remote Tactile Feedback

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ABSTRACT
For the interaction with in-vehicle interfaces such as infotainment systems, the concept of 'one button per function' has worn out. In order to cope with the increasing functionality of in-vehicle information systems, researchers and practitioners are eager to integrate natural user interfaces and multimodal feedback into the car. In the paper, we discuss our approach of Remote Tactile Feedback and present scenarios for direct touch interactions and tactile feedback before and after an interaction.

Author Keywords
Natural User Interfaces, Remote Tactile Feedback

ACM Classification Keywords
H5.2: User Interfaces. – *Theory and methods.*

Keywords
Experimentation, Human Factors

INTRODUCTION
Researchers and manufacturer start to utilize modalities such as gesture and speech input and auditory and haptic output to improve the safety and expressiveness of automotive user-interfaces. We propose to exploit the unique potentials of Remote Tactile Feedback to further advance multimodal in-car interactions. The spatial separation of direct touch input and resulting haptic and tactile feedback has shown to be beneficial in quantitative and qualitative metrics for touch based interfaces; the in-vehicle application of this approach is the compelling next step.

IN-VEHICLE INTERACTIONS
Minimizing the driver's visual and cognitive load is the main objective for designers and engineers of in-car systems. The defined position of the driver and constraints such as permitted distraction times facilitate the development of novel modalities such as gesture and speech input [2]. For feedback from collision warning or avoidance systems, audio and haptic feedback is already widely used.

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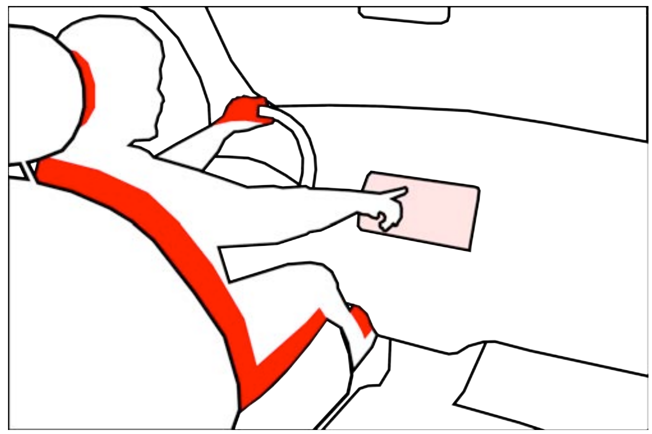

Figure 1: Remote Tactile Feedback can improve and extend touch-based in-vehicle interactions. Colored areas indicate locations on the user's body for the remote application of tactile stimuli.

Nowadays, also many controllers for in-vehicle information systems such as BMW's iDrive[1] are equipped with haptic or tactile feedback. Additionally, due to advantages in usability and flexibility, more and more direct-touch based interfaces such as touchpads or touchscreens find their way into the car. However, the interaction with touchscreens highly depends on visual attention [1], which results in significantly less eye-on-the-road time when drivers interact with touch-based in vehicle systems.

TACTILE FEEDBACK IN THE CAR
Researchers show the highly beneficial effects of active tactile feedback for touch interfaces on error rate, interaction speed and visual load [3]. In a prior work, we present HapTouch, a force-sensitive in-vehicle touchscreen device with tactile feedback that allows the user to explore and manipulate interactive elements using the sense of touch [6]. The results of our user-study indicate positive effects of tactile feedback during touch interactions whilst driving on the errors made during input tasks. This especially holds true for very small virtual elements. However, the variety and expressiveness of generated tactile feedback is limited due to the mechanical complexity and size of actuators. The remote application of tactile stimuli could help here.

[1] www.bmw.com

REMOTE TACTILE FEEDBACK

The spatial separation of direct touch input and resulting tactile output is the basic concept of Remote Tactile Feedback (see figure 1). Moving the tactile stimuli away from the touching fingertip or hand is achieved by integrating actuators in the user's direct environment. Similar to direct tactile stimuli, the remote application of feedback on touch surfaces has positive effects on interaction speed and error rates [4]. Furthermore, this approach has the potential to expand and simplify the use of multimodal stimuli when interacting by touch. For example, in prior work, we describe how to utilize Remote Tactile Feedback to combine rich and versatile tactual characteristics to create novel tactile modalities on direct touch surfaces [5].

SCENARIOS

For Remote Tactile Feedback, electromechanical or electrotactile actuators have to be in contact with the user's body. In the car, large areas of the user's skin can be used to apply various tactile cues: The driver is remaining in a seated position with constant direct contact to the steering wheel, the seat, the armrest or the pedals. We present two possible scenarios of how to utilize the unique characteristics of Remote Tactile Feedback for touch-based in-vehicle interactions:

Direct Touch Interactions

First of all, remote tactile cues can be used to convey standard feedback when interacting with a touchscreen. Resulting tactile stimuli mostly fall into one of 4 categories: During a number input task, the user can manually explore the *form* and function of the on-screen button before it is actually activated. During the manual activation, the altering *state* of the element is communicated haptically. Subsequently, a tactile *acknowledgement* to confirm the interaction could be conveyed using remote tactile stimuli. In addition, *abstract information* such as 'Press Start on Touchscreen' could be communicated even when the user's hand has left the screen. Thus, Remote Tactile Feedback could reduce visual load and enhance safety when interacting via touch.

Tactile Feedback Before and After the Interaction

This scenario is specific for Remote Tactile Feedback: with tactile actuators (e.g. in the steering wheel) in permanent contact with the user's skin, tactile cues on a touch interaction can be given, before, whilst and after the finger actually touches the screen.

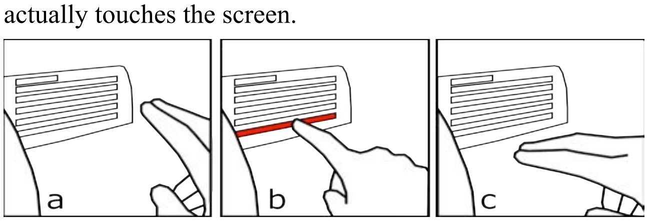

Figure 2: Remote Tactile Feedback can support phases before (a), during (b) and after (c) a direct-touch interaction.

Here is an example (see figure 2): During a list selection task, Remote Tactile Feedback describing the gestural proximity of the finger towards the scroll bar can be given before the finger touches the screen. This results in a form of gestural input: the user approaches the screen with the intention to scroll down a list. Remote tactile stimuli (e.g. from the seat) could inform the user that he is approaching the intended lower part of the virtual list. If the user's finger in front of the screen changes direction, e.g. approaches the list item in the center, the tactile stimulus changes and thus informs the user. This tactile correction could happen in a very short amount of time (e.g. less than 0.5 seconds). The visual load for pointing to the intended screen area is reduced. When the user touches and swipes on the screen the scrolling is performed. After the finger has left the screen, an acknowledgement or the number of passing items is conveyed haptically.

CONCLUSION AND FUTURE WORK

When designing in-vehicle interfaces, minimizing the driver's visual distraction is the primary objective. For touch-based in-vehicle information systems, direct tactile feedback has shown to be highly beneficial in minimizing visual load, reducing error rates and increasing driving performance. The novel approach of separating direct touch input and resulting tactile feedback has the potential to further simplify and expand the use of multimodal stimuli. Due to the driver's defined position and permanent contact with seat, steering wheel and pedal, the car is an appropriate scenario for Remote Tactile Feedback. We briefly described two scenarios of application. The next step is to integrate tactile actuator technology in a car environment. Remote Tactile Feedback could help to improve driving safety and expand and naturalize multimodal interactions in the vehicle.

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Hybrid Interactions in the Car

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ABSTRACT
We present a low fidelity prototyping tool for hybrid interactions on touch-based surfaces with capacitive sensing. Providing physical handles for certain actions on these screens can decrease the visual and cognitive load carried by human drivers, leading to a safer driving experience. Our toolkit allows for the fast and inexpensive simulation of physical interactions on capacitive sensing devices and assists and simplifies the design process of such systems.

Author Keywords
Hybrid Interaction.

ACM Classification Keywords
H5.2 User Interfaces – *Prototyping*.

INTRODUCTION
Capacitive screens are enjoying great popularity within in-car interaction systems due to decreased material costs and their wide acceptance by users. However, one stumbling block remaining is that these interfaces demand a high level of visual attention in the performance of menu tasks. As distraction can lead to hazardous driving situations, resolving this complication is of critical importance. We investigate the use of extending these interfaces with artifacts that support the user through multimodal interaction possibilities. In the automotive research community, these interfaces are considered highly beneficial as they offer more natural-feeling interaction possibilities while reducing distraction.

APPROACH
The toolkit we are currently exploring allows the customization and design of peripheral interactions through tangible user interfaces (TUI) [1] on interactive screens. A tablet computer (as depicted in figure 1) can easily be imagined to be equal in form and size to the central information display (CID) in tomorrow's cars. Recent research projects have exemplified the mechanical possibility of positioning tangible artifacts also on vertical screens [2]. Our implemented toolkit can recognize different objects on capacitive sensing devices (here the Apple iPad) without electronic components. The recognized 3D objects subsequently trigger different GUI elements, offering various interaction possibilities. In an automotive context, this toolkit allows the fast and inexpensive prototyping of user-customized, hybrid interfaces on a low fidelity object.

Figure 1. Tangible low fidelity objects triggering different digital behaviors.

For example, a user who mostly uses the phone book and the playlist feature of the stereo system while driving can attach two distinct physical artifacts to the CID and trigger these actions directly by rotating and pushing them. Due to the rich multimodal feedback from the physical artifacts, the user can *feel* the interaction more directly and naturally. Compared to common touch based interactions, this could result in a reduced visual and cognitive load for the driver. Though the TUIs demand screen space as a tradeoff, more than two thirds of the screen's size is still available for representing additional information like GPS routes or playlists. In light of the reduced screen space, we recommend assigning only frequent actions to tangible artifacts.

CONCLUSION
We believe that prototyping tools as exemplified in this work can be of aid to the flexible prototyping of natural in-car interactions as early ideas can be visualized and tried out quickly and easily during the design process, resulting in substantial advances in making these systems usable and enjoyable.

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Mobile Device Integration and Interaction in the Automotive Domain

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ABSTRACT

People feel very comfortable when they interact with their mobile devices by using natural user interfaces (NUIs). However, when they enter a vehicle, this feeling degrades rapidly, since many in-vehicle infotainment systems (IVIs) still do not offer natural user interfaces and use different user interface interaction paradigms. For this reason, we show how mobile devices can be integrated and used in the automotive domain. We first elaborate on architectural concerns and then summarize possible benefits of a mobile device integration. A basic set of interaction scenarios is presented in order to show how integrated mobile devices can contribute to NUI experience in vehicles. Finally, two available approaches are introduced and their potential for NUI integration is initially evaluated.

Author Keywords

Mobile device integration, nomadic device, NUI upgrade.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: Miscellaneous

INTRODUCTION

Mobile devices, such as smart phones and tablet PCs, are today's most popular devices that offer natural user interfaces and will be used for interacting with future internet services [5]. People of all ages use those devices by performing intuitive (multi)-touch gestures and using the interactive voice response (IVR) systems, due to the easy learnability of natural user interfaces. The ease of use and the availability of interactive and useful applications made mobile devices daily companions. They provide services like location-specific information, user-preferred multimedia content, mobile internet access or comprehensive communication, anywhere anytime. However when a mobile device user enters a car, the "anywhere, anytime" seems to end. Although many automotive manufacturers already integrate connected in-vehicle infotainment (IVI) systems in their cars, these systems are often at their very beginning, and thus are only offering some basic user interfaces. In many mid-sized cars or compact cars, there is often no head unit at all. Integrating mobile devices into the vehicles' IVI systems could solve many problems related to NUI and IVI.

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Based on the current development, we give examples how natural user interfaces of mobile devices could be used in the automotive domain. We first motivate the mobile device integration by giving examples. We then give an overview of possible architectural integration methods. The second part shows, how interactions between the IVI and the integrated mobile devices could be designed. Table 1 gives an overview of possible interaction scenarios and the different roles of the mobile device and the IVI system. Finally, we classify two currently available systems for integrating mobile devices in vehicle systems by means of their integration method and interaction possibilities.

BENEFITS OF THE INTEGRATION OF MOBILE DEVICES

Mobile devices are used by people of all ages, due to the easy learnability of natural user interfaces. Norman, in his article "Natural user interfaces are not natural" [7], supports this, but also highlights, that natural user interface paradigms are still not standardized and, for that reason, people have to get used to each different system they use. It can be observed that most users are more familiar with the handling of their mobile devices, than with handling different in-vehicle infotainment systems. Especially while driving, it is important that the user can interact with the IVI without having to concentrate on the handling itself. This can, for example, be achieved when the mobile phone is used for interpreting the gestures or voice input. Sonnenberg claims that "[t]he system shall respond in a clear, predictable and consistent way [...]" [9]. We believe this can be achieved with mobile devices, since the user is familiar with their mobile device's system, and can comprehend and predict the behavior of it.

Another benefit of using mobile devices together with – or as a replacement for – embedded in-vehicle infotainment is the ability to bridge the lifecycle gap between automotive and consumer devices. By now, the lifecycles of automotive hardware and software can be measured in years and decades. In contrast, the lifecycles of smart phones and tablet PCs are measured in months or years. In 2010, mobile device owners in the United States replaced their hardware on average after one year and nine months usage[1]. The lifecycle of mobile applications can be measured in weeks or months today. Automotive manufacturers try to keep track with the innovation cycle of consumer devices, but a real affordable possibility for updating or upgrading in-vehicle infotainment systems is not yet in sight. In general, only new models benefit from new systems. In addition to the lack of update possibilities,

[1] `http://mobilefuture.org/page/handset-replacement-cycle.pdf`

the specialized solutions for the in-car systems are often very expensive. A simple embedded navigation system can easily cause up to 3,000 Euro extra costs for a new car. The following yearly map updates cost on average between 150 and 200 Euro. Assuming a car lifetime of 10 years, the user could also use the money to buy a new up-to-date mobile device (including up-to-date maps) every year. Despite of having updated software, the user would also have new hardware and could directly benefit of updated interaction possibilities, and thereby NUIs.

Natural user interfaces consist not only of gestures and IVR systems. The inclusion of contextual information is also an important factor. Especially mobile devices, as ubiquitous personal devices, can access, calculate and provide a lot of information and data of their owners to adapt and contextualize in-vehicle infotainment systems. They are configured and adjusted to fit the user's needs. A simple example is the user's language that could be derived from the language set on the mobile device and thus be set for the in-vehicle interfaces. Most users also use their mobile device as calendar, and thus the device could derive where the user probably wants to go or when he/she should arrive. The navigation system of the mobile device can access the contact list and could automatically calculate routes to friends or meeting partners. Whereas saying "Navigate me to John Doe's working address" would confuse a classical in-vehicle navigation system, a mobile device based system could use its additional context-information to correctly interpret the user's command. The mobile device, a personal assistant, never leaves our side. It could also be used for storing in-car preferences, such as the preferred seat adjustment or temperature. This would simplify changing from one car to another car. As a kind of digital memory, the mobile device could enable a more energy efficient and more comfortable driving. For example, the known route, the driver's way of driving, which could be stored on the mobile device, and information from digital maps could be used to predict the charge levels of hybrid electric vehicles. Based on these predictions, the charge profile could be optimized: for example, driving up a hill could consume the whole battery charge, since it would get charged anyway during driving down.

Coupling the mobile device to the IVI would also enable transferring states between the systems. For example, when a user cannot park their car near the destination, the navigation task can be split up. In a first step, the system navigates to a parking lot and when the user leaves the car, the mobile device shows him/her the way to the destination. By using the internet connectivity of the mobile device, this could even incorporate public transport. At the same time, the mobile device can remember the position of the parked vehicle and lead the user back to it afterwards.

INTEGRATION OF MOBILE DEVICES

The integration of the mobile device into the vehicle's system is a key point in order to create a system that can benefit of the coupling. Besides thinking about the physical connection, one has also to consider the data interface. For the physical connection, there are, in general, two possibilities: *wired* and *wireless*. The following list describes wired connections that are commonly supported by mobile devices:

- Universal Serial Bus (USB): Up to 480 Mbit/s (for USB 2.0) bidirectional multipurpose link with charging support.
- Mobile High-definition Link (MHL): Charging and at the same time 1080p high-definition (HD) video and digital audio output via a single low pin-count interface.
- High-Definition Multimedia Interface (HDMI): Uncompressed HD video (inclusive 3D video) and digital audio output.
- Audio Line-In/Line-Out: Analogue audio input/output.

Modern docking stations allow an easy connection of the different wired outputs. Most mobile devices further have an option to detect whether they are docked to a car docking station or to a normal desk docking station. This allows, for example, automatic switching to a car optimized user interface with larger icons, or to switch off animations which could distract the driver. On the wireless connection side, the most common links are:

- Wireless Local Area Network (WLAN): Multipurpose network connection with a theoretical maximum throughput of 600 MBit/s (for IEEE 802.11n, 2.4 and 5 GHz)
- Bluetooth: Different protocols allow various communication types, for example audio distribution or IP networking.
- Near Field Communication (NFC): Simplifies device pairing and enables secure data transmission (up to 424 kbit/s) for a very limited distance.
- Mobile Network: Telephony and data services.

Figure 1. ***paragon's cTablet Docking Station*** **enables docking the tablet PC** ***Samsung Galaxy Tab 7.0"*** **in two normed car mounting bays. Source:** ***paragon AG***

Although inductive charging solutions are available for several years now [2], there are still only a few mobile devices that actually can be charged wireless. A wired connection with charging support is preferable for longer journeys. Dependent on the required data exchange between the mobile device and the car system, one has to choose the right connection type. When the mobile device shall be used as input and output unit at the same time, bidirectional multipurpose links, such as USB, WLAN or Bluetooth, are a good choice. For the output of multimedia content MHL, HDMI or WLAN with DLNA (Digital Living Network Alliance) software support could be used. A combination of different connection links allows high flexibility and performance at the same time. Especially when services should be provided for all car occupants, a wireless data or multimedia connection is the most convenient solution. The same applies for short trips, since the driver can leave their mobile device in the pocket. When femto-cells get integrated in vehicles, the mobile network could also be used for the coupling by providing the network for the car occupants.

The *cTablet Docking Station*[2] from *paragon AG* is shown in Figure 1. It allows connecting a 7 inch Android tablet PC to the car via two normed car mounting bays at the vertical center stack. The device is charged via USB and the connection to the car's system is established using Bluetooth. The example shows another key issue of integration the mobile device in the vehicle: especially when the mobile device should be used as head unit, and thus also should provide the natural user interface, it is important to put it to a place where the driver can interact with it in a natural way with eyes still being (mainly) on the road. Kern et al. [3] present an overview about the design space for driver-based automotive user interfaces. These investigations provide a good starting point for thinking about a suitable position where the mobile device could be placed in the car for interaction. This design space has, so far, not been defined conclusively. When the mobile device's display is used for output, it should be placed somewhere at the vertical part of the car where the driver can look at without looking too far away from the street. The mobile device can also be used as input device only. For example, it could be mounted at the horizontal center stack and the user can perform multi-touch gestures on the switched off touch display.

Another important challenge is the establishment of the in-car data interfaces. Since automotive innovation cycles are still measured in multiples of years (even 10s of years), a well-conceived, comprising and extensible interface has to be specified. A high-level solution, which is detached from the low level communication systems of vehicles, is highly preferable. There should be no need to interface directly with the in-car bus systems, such as CAN (Controller Area Network) or MOST (Media Oriented Systems Transport). Kranz et al. [6] proposed an open-access vehicular data interface for in-car context inference and adaptive automotive human-machine interfaces. An advantage of the system is that one can easily read out the current car state without the burden of acquiring a CAN matrix. The CODAR viewer [4] is an example for a situation-aware driver assistance system based on vehicle-to-x (V2X) communication. It demonstrates how V2X data can be provided efficiently to a visualization system. Slegers [8] shows how the integration of a personal navigation device (PND) in the car system could look like. He also introduces the *Reflection Interface Definition* (RID) language that allows simple description of changing interfaces. Those data interfaces are mainly focused on the context exchange part of the integration.

For interacting with natural user interfaces using gestures on a touch display or speech interaction in vehicles, another set of interfaces are necessary. Human interface device (HID) classes are, for example, available for USB and Bluetooth. These base classes can be used or adapted for many input and output devices. Depending on the role of the mobile device, it can act as *host* or as *device*. When it is used as head unit replacement, it can work as a *host* and receive and interpret inputs from other car input devices, such as buttons, sliders or knobs. When the device is acting as input device, it can register itself as a *device* and provide inputs for the car system. Camera images, that can be used for gesture recognition, or audio input for interactive voice response systems can be transferred using available multimedia protocols for USB or Bluetooth. When an IP network connection is used, streaming protocols like the Real Time Streaming Protocol (RTSP) can be used.

INTERACTION WITH INTEGRATED MOBILE DEVICES

There are various ways, how an interaction between the integrated mobile device and the car's system could look like. For a simpler overview, we have summarized some common cases in Table 1. A combination of several scenarios will be actually used in many cases. A clear distinction is not always possible.

Looking at the different scenarios, one can derive benefits for a natural user interface from each single scenario. Even when the mobile device only acts as content provider, it can be beneficial for a natural user interface. It is most likely that the content on the phone describes the user's preferences. The content can even be used for deriving contextual information, such as preferred music genre by scanning the collection on the phone. The connectivity provider scenario can be considered as a support technique. It allows, for instance, connecting to social networks and cloud services using the user's private credentials that are stored on their mobile device.

CURRENT APPROACHES AND AVAILABLE SYSTEMS

Automakers and suppliers have developed already several interfaces for integrating mobile devices in the IVI systems. *MirrorLink* (former called *Terminal Mode*) [1] is the open industry standards solution of the Car Connectivity Consortium[3]. This protocol is an example for the *Head unit as mobile device remote display/control* scenario of Table 1. It uses IP technologies over USB and WLAN. Virtual Network Computing (VNC) is used for replicating the phones display on the head unit and to send key and touch events back to the mobile device. Audio can be streamed via Real-Time Protocol (RTP) or via the Bluetooth audio profile. This system allows using the natural user interfaces of the mobile device directly on the vehicle's human machine interface (HMI). Since the mobile device is used as the main system, the state is preserved on entering and leaving a vehicle.

iPod Out[4], developed by *Apple* and *BMW*, is an example for the "mobile device (MD) as partial user interface provider"

[2] http://www.paragon-online.de/en/2011/06/07/artikelblock-2/

[3] http://www.terminalmode.org/en/agenda/consortium

[4] https://www.press.bmwgroup.com/pressclub/p/gb/pressDetail.html?outputChannelId=8&id=T0082250EN_GB&left_menu_item=node__2369

Interaction scenario	Role of in-vehicle infotainment (IVI) system	Role of integrated mobile device (MD)
MD as head unit	Provides vehicle parameters, gateway to different input and output systems (e.g. audio).	Provides all applications. Touch display used for input and output.
Head unit as MD remote display/control	Provides a display and can forward inputs to the mobile device. Only basic applications are running on the system.	Provides most of the applications. Sends output to the built-in head unit. Accepts inputs from IVI.
MD as partial user interface provider	Provides main interface. Allows to integrate external UI in selected views.	Provides UI content for the IVI.
MD as content provider (portable cloud)	Built-in head unit can request information from the MD. Provides all applications.	Provides access to e.g. available multi-media content, calender or contacts.
MD as context provider	Runs applications. Handles context itself.	Provides context such as language settings or saved seat adjustments.
MD as input device	Has own display. Runs applications.	Sends inputs such as detected touch gestures or evaluated speech input to the IVI.
MD as connectivity provider	Runs applications, uses telephony and internet connection of mobile device.	Mobile device provides telephony and internet connection to IVI.

Table 1. The mobile device's and the in-vehicle infotainment's roles for different interaction scenarios.

and "MD as content provider (portable cloud)" scenarios. A TCP/IP connection via USB or Bluetooth is used for transferring rendered images of the media gallery from a connected *Apple iPhone* or *iPod* to the HMI which displays the received content in a reserved view area. This allows the user a fast recognition of the displayed content, since the content is presented to him/her in the same way as it would be displayed on the mobile device itself. The system can be controlled via the HMI of the car. Since it has the same layout and follows the same interaction paradigms, the user can benefit partially of the mobile device's natural user interface. The car audio system is used for playing the selected content.

CONCLUSION

Mobile device integration in the automotive domain allows using the advanced natural user interfaces of the mobile device for the in-vehicle infotainment system. In order to enhance the experience for the users, it is important to choose the appropriate integration architecture. Besides selecting a physical connection type, future-proof standardized data and interaction interfaces have to be established. In this work, we summarized possible architectural approaches and provided a set of interaction scenarios. By describing the respective roles of the IVI system and the mobile device for those scenarios, we highlighted, what combinations are possible and what benefits result from the mobile device integration.

Considering the current available systems, one can recognize that there are already some usable approaches. It is for us, to use this technology in order to bring natural user interfaces into vehicles.

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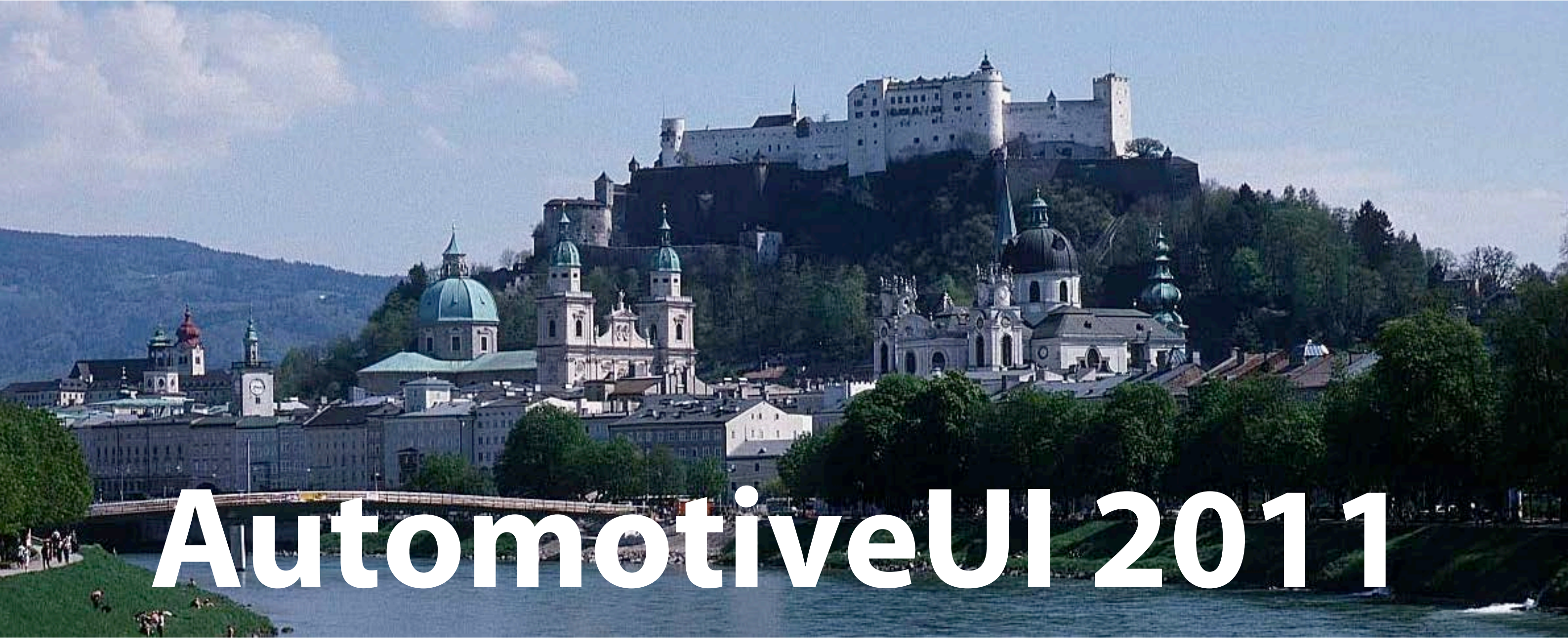

AutomotiveUI 2011

Third International Conference on Automotive User Interfaces and Interactive Vehicular Applications

November 29—December 2, 2011
ICT&S Center, University of Salzburg
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Adjunct Proceedings
Workshop “Integrating Mobile Devices into the Car Ecosystem – Tablets and Smartphones as vital part of the Car”

Workshop Organizers:

Steffen Hess	Fraunhofer IESE
Alexander Meschtscherjakov	University of Salzburg
Torsten Ronneberger	AUDI AG
Marcus Trapp	Fraunhofer IESE

In-Car Contextualised Search on Tablets

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ABSTRACT
In the last few years, an increasing number of portable devices have entered the vehicle, creating opportunities for a number of services and applications targeting drivers and passengers. This is likely to lead to an information overload for the vehicle occupants – with safety implications if the applications are targeted to the driver. Therefore the ability to explore information safely in such applications becomes not only important – but safety critical. Generally the search functions in such application use of the "search engine interaction model" which is not optimal for in-car usage. In addition, the interaction and visualization in those applications do not account for passengers as potential users.

In this paper, we present the SafeTRIP Info explorer which uses an innovative interaction and visualisation model for in-car usage. Preliminary results of in-car field trials evaluating SafeTRIP Info Explorer have generated encouraging results. These are presented and discussed.

Keywords
Tablet, Search, Information Exploration, UI, SafeTRIP

INTRODUCTION
While in-vehicle services and applications for drivers and passengers have been around for over a decade, the last few years has seen an impressive growth in this area due to advances in portable devices and mobile communication. The most popular service is personal navigation support, which over the years has grown to include information beyond map and route – information about traffic, points of interest, hotels, petrol stations, restaurants, weather, etc. While the availability of such information is useful for drivers and passengers, they are integrated with the navigation application on devices with relatively small screens. It makes both information search and access to rich detail difficult and dangerous - if operated by the driver on the move. In addition, it disrupts the use of the device as a navigation tool. Indeed, it is becoming more and more common, for applications running on nomadic devices (e.g. tablets, smartphones) to be used in the vehicle for this purpose, however in general these are not designed for in-car usage – and therefore suffer from limitations (for instance, long textual presentation of information which is difficult to read on the move).

A survey with drivers in the context of the SafeTRIP project revealed that there is need for 1) content - information with rich level of details (including embedded multimedia) 2) better search mechanism – as current text-based searches are seen as limiting. It also emerged that for practical and safety reasons, many drivers delegate the task of searching and information access to a passenger or use the device to search when the vehicle is parked.

Through the use of tablets it is possible to address the unmet needs of drivers. In this paper, we present the design for the Info Explorer service on the SafeTRIP platform – capable of delivering rich geolocalised information to vehicle occupants. We equally present findings from the in-car evaluation of the UI and interaction design. The paper concludes with recommendations for in-car application design.

RELATED WORK ON INFO EXPLORATION AND IN-CAR UI

Information Exploration
Traditional information exploration through search engine result pages (SERP) is primarily designed for navigational search, or for simple information tasks (such as checking a fact on Wikipedia). However with more complex information problems, when users want to get a broader view and consult different sources or different aspects of an information problem, the search experience using SERPs is far from ideal. Even map based applications with search capabilities – such as Google Map on Android - still use this paradigm on tablets.

Figure 1 shows the screens when petrol stations are searched on the Android Google Map application. The result is presented as a list of petrol station (with address and an image) and corresponding markers on the map.

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The selection of any petrol station clears the list and displays a new page with information only about the selected station. The user has to navigate ‘back’ and ‘forth’ between the search result list and the details page for each petrol station in order to compare information.

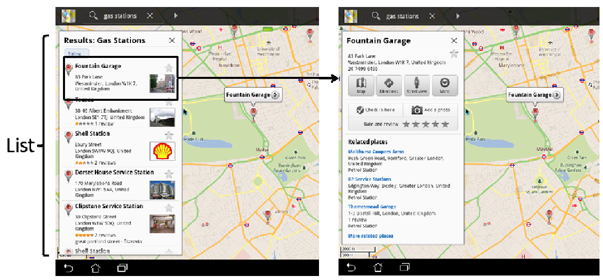

Figure 1 - Search result for petrol station as list in map-based tablet application

The *search engine interaction model* (Figure 2, left side) illustrates users’ interaction with SERPs, moving back and forth between search results (A, B, C, D) and the actual SERP (central point).

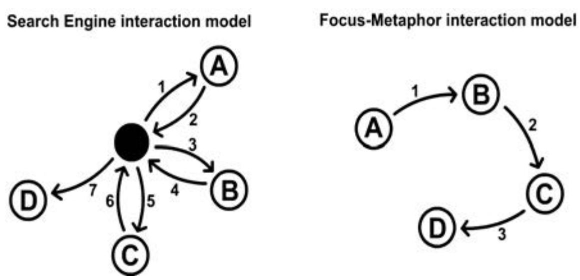

Figure 2 - Contrasting Interaction Models

However, none of the alternative approaches such as contextual search [6] and search result clustering [7] challenges the current paradigm of how users interact with the results. This becomes the more apparent when considering that the user is performing the search in a moving vehicle. For instance, the driver may want to search for a petrol station with the cheapest fuel and with a cash machine – this would require exploration of the facilities and comparison of the pricelist of many petrol stations – a tedious task using the paradigm described.

In-Car UI

The majority of research on interactions with in-car information systems has focused on the driver and the devices that are integrated in the vehicle or used primarily for navigation. Comparatively fewer works – if at all - have looked at the user experience of systems targeted at tablets for use by both drivers and passengers. Any system for use by drivers must prioritise safety of use, for obvious reasons. Such systems provide a poor user experience from a passenger’s point of view, but may also exclude the passenger from effectively using such a system. Yet, a system that considers both passenger and driver requirements may ultimately provide a better and safer experience for both. In their work, Inbar and Tractinsky [5] refer to passengers as “incidental users”, who can “buffer the driver from information overload”. They argue that “the traditional, driver-focused design of car dashboards, entirely overlooks this possibility [of sharing information with passengers]”. Inbar and Tractinsky raise a number of interesting motivations for designing IVIS that are more inclusive for passengers in front or back seats, however their primary focus is on how existing driver dashboards may be re-designed. Yet with the emergence of a whole new range of mobile devices, smart phones and tablets in particular, dedicated devices that can serve as a passenger-centric front-end to IVIS become increasingly relevant. Focusing on a dedicated user interface for passengers introduces an entirely different set of user requirements than one would apply to driver-centric user interfaces.

In Beeharee et al. [1] the authors discuss the application of a dedicated information exploration user interface for “intelligent in-car services” which is designed to address the limitations described above. While it was initially discussed as a potentially effective driver-centric interface, in this paper we explore its applicability as a passenger-centric interface. In contrast to traditional search user interfaces, the described information exploration interface – also referred to as Focus-Metaphor Interface (FMI) [3] - enables seamless exploration of the underlying information spaces

SAFETRIP

From our study, it is evident that information exploration is more frequent during long trips across unfamiliar region and beyond country borders. The requirements for high bandwidth and geographical coverage call for connectivity solutions beyond cellular network – which typically suffer from poor coverage along much of the road network in uninhabited regions. The SafeTRIP project [2] aims to utilize a new generation of satellite technology to improve the safety, security and environmental sustainability of road transport. The project will deliver an open platform that exploits the advantages of the satellite communication component to allow for innovative and sustainable automotive services.

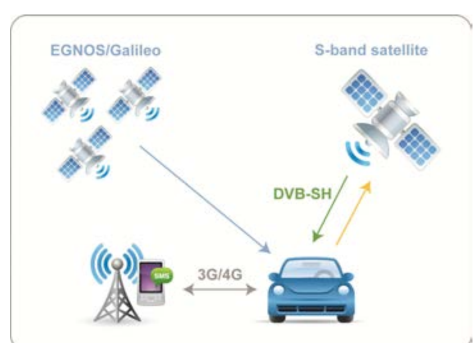

Figure 3 - The SafeTRIP concept

SafeTRIP [8] is an Integrated Project (IP) co-funded by the European Commission (DG Research) with 20 partners from 7 European countries, representing partners in research and business with a wide range of interests and expertise, coordinated by the motorway company Sanef of France. The partners include road operators, satellite companies, research centres, transport operator, insurance companies, equipment manufacturers and academia. SafeTRIP started in October 2009 and will last 3.5 years; one of its main objectives is to improve the use of road transport infrastructures and to optimize the alert chain in case of incidents – this will be achieved through an integrated system from data collection to safety service provision.

SafeTRIP Platform

While being open and capable of integrating other communication technologies (such as Ground Networks), the SafeTRIP platform operates over satellite on the S-band frequency range, which is optimized for two-way communication for On-Board Units (OBUs) in the vehicle (Figure 3). The S-band communication requires only a small omni-directional antenna on the vehicle - making it suitable for the mass market. Unlike cellular networks, the broadcast capability of the S-band is well suited for sending large amounts of rich information to multiple vehicles – which is important to provide a scalable and sustainable solution to address the need for rich information by drivers.

Info Explorer Service

SafeTRIP Info Explorer service runs on the SafeTRIP platform and is designed as a personalized information portal for vehicle occupants offering travel-related information (including POIs). As shown in Figure 4, information from multiple sources (e.g. security alerts, traffic information, local regulations, weather forecast, POIs, etc.) is collected by an aggregator system in the service centre. The rich information – which is a mix of static (e.g. shop facilities at a petrol station) and dynamic (e.g. current fuel prices at the petrol station) types - is then transmitted to all vehicles equipped with the SafeTRIP OBU using datacasting technologies to reach a large number of vehicles with one single transmission.

The geolocalised information, filtered based on the vehicle's position and the user preferences, can then be formatted and presented to the users using either the vehicle's inbuilt interface (video and/or audio) or the end-user devices (e.g. tablets, smartphones or laptops) through a local web-server. These devices communicate with the OBU via WiFi. Users can explore information within the system primarily through topical information channels, such as hotels, restaurants, news, places to visit, etc. In the current prototype, the number of available information channels is limited - acquiring rich travel-related information that is geo-coded, includes images, a description and that is also available for offline archival and re-use requires significant effort.

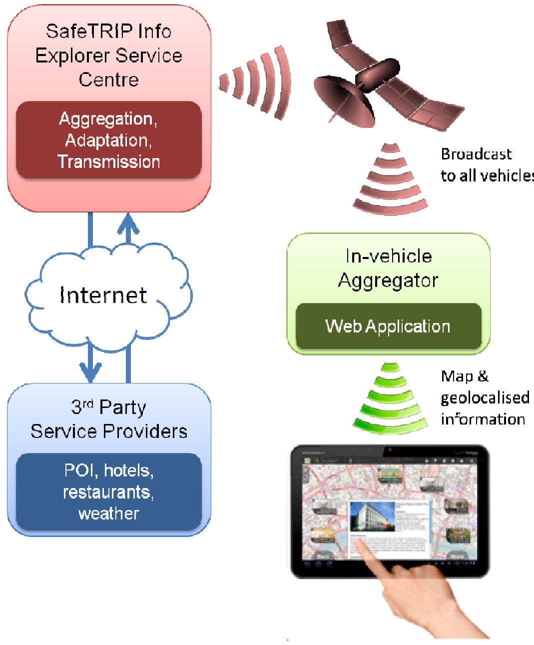

Figure 4 - SafeTRIP Info Explorer Architecture

The current prototype offers 4 channels for the London area:

1. Hotels (with images, geo-codes and rich text descriptions)
2. Public toilets (with images, geo-codes and textual location information)
3. Petrol stations (with images, geo-codes, brand, shop facilities, opening times, contact details)
4. Parking (with images, features, address)

In the UI of the application, the Focus-Metaphor Interface (FMI) has been integrated with a map backdrop, which provides preview information of relevant SafeTRIP Info Explorer items in the vicinity of the current GPS or user selected location overlaid on top of the map. In its current iteration, SafeTRIP Info Explorer is optimized for the landscape format (Figure 5).

Figure 5 - UI of Info Explorer

The first 7 results are displayed as previews through the FMI map overlay in a semi-circular manner- accounting for Miller's famous considerations of short-term memory capacity [4]. A preview consists of an image, a descriptive phrase and a labelled reference to the marker on the map in the top left corner. The *Channels* button toggles the visibility of available information channels. The *Target* button toggles a ‘target marker’ on the map which is used to specify a location for which nearby items are displayed. The marker can be moved anywhere on the map, allowing the user to re-query previews. The *Marker/Link* buttons allow the user to choose between the three information link modes – Google style markers, coloured markers and transparent arrows - that associate the preview with locations on the map.

IN-CAR FIELD STUDY

The aim of the study was to evaluate the use of the SafeTRIP Info Explorer in a naturalistic context in performing information search efficiently and effectively – with a view to assist the driver in finding certain services. The participants would meet two experimenters in the car park. The car was equipped with an in-car navigation application that was used to simply display the map and current location during the study.

One experimenter was the driver and the other acted as the passenger in the back seat. All three car occupants created a ‘virtual friendship’ on a road trip. The experimenter drove the car around the city for two hours. The participant was encouraged to think-aloud throughout the session focusing on discussions about the information exploration and UI. The session ended with a brief questionnaire.

Figure 6 - Participant using Tablet in the Car

16 participants (11 males and 5 females) aged between 19 and 46 were recruited through adverts on notice boards and mailing lists. Half of the participants owned a touch-enabled smartphone, the other half had tried one. Four of the participants owned a tablet device, and all but one participant had tried one before.

PRELIMINARY RESULTS AND DISCUSSION

12 participants used the map in the application to locate themselves, find location of places, estimate travel distances and assist the driver in terms of navigation. The rest focused on the information itself, leaving navigation entirely to the driver.

All participants familiarized themselves very quickly with the information layout and tools – commenting that the preview items and the links to the map supported quick comparison of results, allowing them to make a selection – this was in spite of the layout being very different to a traditional search listing that they are familiar with. In addition, all participants reported that the linking strategy of coloured marker and transparent link was better compared to traditional Google-type markers.

During the trial, some participants experienced issues with the positioning as the tablet used the inbuilt GPS sensor. It would be preferable for the application to use the car’s positioning system which seem to work better under similar conditions. The next version of SafeTRIP Info Explorer will use this approach.

Structured information with short phrases (used for petrol station channel) as rich description was preferred over text description (used in hotel channel) – even if the later had more useful information. The majority of participants reported discomfort when reading text for a long time in the moving vehicle.

CONCLUSION

Smartphones have already invaded the vehicle; it is only a matter of time before tablets do. However, tablets are much more versatile and can bring a number of benefits to the occupants. As shown by this study, application developers targeting these devices should account for their potential in-car use. The UI design and interaction paradigms should lend themselves well to in-vehicle usage – such as the FMI approach for searching, exploring and visualization rich data, the *Target* for redirecting searches and linking strategies to minimize cognitive load to associate rich previews with map locations. The application itself should allow for personalization (e.g. choice of map provider) and be able to interact with other in-car systems (e.g. for positioning and communication) as well as other applications (e.g. pushing a new destination to the in-car navigation application from the tablet).

ACKNOWLEDGMENTS

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Position Paper – Integrating Mobile Devices into the Car by using Standard Web Technologies

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ABSTRACT
Providing a framework to connect state-of-the-art mobile devices and to add third party applications to the in-vehicle infotainment (IVI) system is a number one priority among Original Equipment Manufacturers (OEMs) worldwide. In this position paper, we analyze different approaches for a future middleware for the integration of mobile devices into cars from a scientific point of view, highlighting the benefits for both OEMs and 3rd Party Developers targeting mobile platforms. We propose a future middleware architecture and argue, why established and platform independent Web Technologies should be used for future in-vehicle device integration.

Keywords
In-vehicle infotainment; Web Applications; automotive user interfaces; mobile device integration; middleware.

INTRODUCTION
The success of Smartphones is not only dependent on the features they provide off-the-shelf but rather on the software available for the platform they are running. This is the reason for two important problems arising for in-vehicle infotainment in general and for the integration of Smartphones into cars in particular:

1. Providing individual solutions that meet the high requirements of the users of mobile software becomes too costly for car manufacturers.
2. The number of features available for Smartphones is growing exponentially. Even for a subset of these features, it is highly complicated to provide fine-grained car integration without including 3rd Party Developers into the integration process.

Some off-the-shelf infotainment platforms are already available in the market and have successfully made their way into production cars. While off-the-shelf platforms fit perfectly well to standard infotainment services that are shipped with the vehicle, it still remains challenging to provide a middleware that is capable of integrating future devices and services [1].

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In the following, we summarize recent approaches for such a middleware. Afterwards we describe our position towards a future middleware, pre-empt possible counter arguments and then highlight the benefits of our solution.

STRATEGIES FOR MOBILE DEVICE INTEGRATION
Latest middleware approaches providing deep integration of mobile devices into cars can be divided into four groups:

The first group is based on proprietary solutions like for example the Ford Sync system, the Daimler Smart iPhone Drive Kit or the iPod Out interface. These work only for certain car makes and models or certain mobile devices and might become outdated with the next device and platform generation.

The second group is based on User Interface generation as described by Stolle, Saad and Weyl [2]. While offering advanced adjustments to different target IVI systems, this solution depends on complex transformation schemes and ontologies which are not widely spread at the moment.

The third group uses the IVI system as remote terminal for Smartphone applications as described by Bose, Brakensiek, Park, and Lester [3] [4]. This solution can be easily transferred to IVI systems and Smartphone platforms of the whole market range. However, the possibility to adapt the User Interface of mobile devices to different IVI systems in a specific way is limited. While input controls from the car are mapped to controls of the mobile device, the graphical presentation is directly copied from the mobile device. Therefore, it is up to mobile applications to provide graphical user interfaces that fit all compatible car makes and models and that meet automotive requirements. The solution allows to manually provide content descriptions in order to filter out features that are inappropriate while driving. However, due to the characteristics of the system, this filtering is limited to blanking out the screen completely.

The fourth group uses established Web Technologies for mobile device integration. Recently, these technologies have evolved to a serious middleware because they are present on a large number of platforms and because latest HTML5 extensions allow for strong interaction with devices. Our solution that is described in [5] and [6] is based on such technologies. It is summarized below.

OUR ARGUMENT
Only an open and standardized high-level software platform based on existing Web Technologies attracts a reasonable number of 3rd Party Developers, is capable of

integrating past, existing and future mobile devices into cars and at the same time offers adequate mechanisms to adjust applications at runtime to meet automotive requirements.

POSSIBLE COUNTERCLAIMS

- A high-level platform running 3rd party software might not fulfill legal requirements for IVI systems [4].

This claim is certainly true for all solutions that are capable of integrating 3rd party applications into the head unit's HMI. While it might always be necessary to test and approve foreign applications for in-vehicle use, high-level applications offer several advantages. They are constrained to a limited set of features of an approved application programming interface (API) and can only use approved functions to interact with the driver. We are convinced that high-level applications offer the best opportunities for automated tests and automated adjustments towards a target IVI system, as described later.

- A common platform makes it difficult for OEMs to differentiate their products from each other [2]. Especially the HMI is known to be relevant for differentiation of IVI systems [1].

The same is true for Smartphones, nevertheless vendors cooperate to take advantage of economies of scale. In the near future, cars might as well be valued by buyers by the number of popular 3rd party applications they support. As described later, we believe that compatibility to a broad range of other platforms is important in order to establish a platform attractive to a reasonable number of developers. Nevertheless, a high-level platform also offers advantages for differentiation as described in the paragraph 'Advances for car specific Adoption'.

- A high-level platform drastically reduces the number of available applications and is not capable of running or displaying legacy Smartphone applications [4].

We are convinced that this is not a limitation but an advantage of high-level platforms. While other platforms need to deal with the difficult problem to filter out all features that are inappropriate while driving, a high-level platform restricts application components to approved features.

- It is insecure to execute 3rd party software in cars [4].

We agree, that it will still remain necessary to test and approve 3rd party software in order to allow execution in an IVI system. Nevertheless, high-level Web Applications are executed in a browser sandbox and thereby divided from the native IVI system.

OUR SOLUTION FOR DEVICE INTEGRATION

Our platform [5] [6] is based on a Web Application Framework as common middleware across multiple mobile and automotive platforms. A prototype we developed targets Google Android as mobile platform and a research IVI system, but our software might be easily transferred to other platforms as well. Figure 1 gives an overview of our software architecture. Web Applications are transmitted to the IVI system so that it can adapt them and control their execution. In comparison to standard Web Browsers, the Web Application Framework provides additional software interfaces to Web Applications that connects them with the underlying platform.

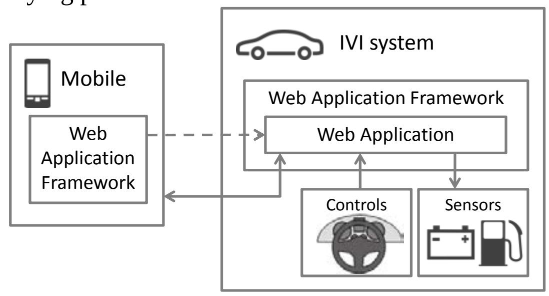

Figure 1: Distributed Web Application Framework

We extended the open source Web Application Framework 'PhoneGap' [7] by methods for accessing vehicle specific controls and sensors. Additionally, we added remote procedure calls to the framework in order to communicate with remote devices. Figure 2 shows a Messaging Web Application on a Smartphone and on an IVI system. When executed in the IVI system, styling and sizes of User Interface elements of the Messaging Application are adapted.

Figure 2: Messaging Web Application

PRODUCT LIFETIME ISSUES

Cars tend to have much longer life cycles than mobile devices. Therefore, it is very important to provide a solution that is capable of interconnecting future mobile devices with unknown features. Legacy Smartphone applications might become obsolete with the next version of their platform. Experiences with Web Technologies are more promising: While the future impact of certain mobile platforms is difficult to predict, Web Technologies have shown to stay stable over years and are known to be backwards compatible to a high degree.

COMPATIBILITY TO OTHER MOBILE PLATFORMS

Compared to Smartphone application development, IVI is a niche market. The number of cars produced by a single OEM comes not even close to the number of Smartphones shipped by huge Smartphone vendors. In 2010, 1.6 Billion Mobile phones were shipped (of which were approx. 300 Mio. Smartphones) [9]. In the same year, OEMs produced about 78 Million vehicles [8]. Table 1 shows the annual production lots of the top five car manufacturers in 2010 and the number of Smartphones shipped for the top five Smartphone platforms in the same year. According to

Gartner, Smartphone sells have grown rapidly in 2011 with 108 Mio. Units shipped in Q2 2011 which is a plus of 74% in comparison to Q2 2010 [10]. This illustrates, that any proprietary platform offered by a single OEM is probably far less attractive to 3rd Party Developers than established Smartphone platforms with a huge user base.

OEM	**Vehicles produced**
Toyota	8.56
G.M.	8.48
Volkswagen	7.34
Hyundai	5.76
Ford	4.99
Others	42.6
Total	**77.7**

OS	**Units shipped**
Symbian	111.6
Android	67.2
RIM	47.5
iOS	46.6
Microsoft	12.4
Others	11.4
Total	**296.6**

Table 1: Top five car producers and Smartphone platforms 2010 (units in Million) [8] [9]

According to this and the before mentioned lifetime issues, we believe that it is necessary for future automotive platforms to stay compatible with as many other platforms as possible in order to attract 3rd Party Developers.

Web Application Frameworks extend standard browsers by additional platform functions like telephony or contacts access. Standardization of such device functions is ongoing at the World Wide Web Consortium [11]. By utilizing a Web Application Framework which is implemented for many Smartphone platforms, our framework and its extensions need to be adapted only once for each new platform. Afterwards, the same HTML5 applications can be executed on all platforms without the need for adjustments or recompiling. As both sides interpret the same HTML5 code, it is possible to exchange applications in both directions – the car might offer applications to mobile devices as well.

REASONS FOR INCLUDING 3rd PARTY DEVELOPERS

While standard infotainment systems have a manageable set of features, the quantity of available applications might grow quickly when 3rd Party Developers get involved, as the recent history of mobile phone platforms has proved. However, as mentioned before IVI is a niche market compared to Smartphone application development, and experts are rare. This leads to a tradeoff between a limited number of IVI applications developed by vehicle experts and a huge number of IVI applications developed by 3rd Party Developers as depicted in figure 3.

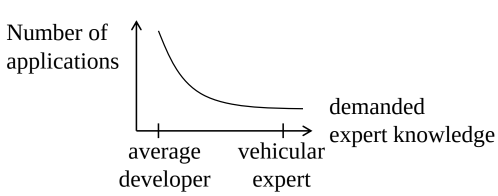

Figure 3: Trade-off for 3rd party IVI applications

As stated by automotive experts in [1], software costs will grow to the half of the overall costs of IVI systems in the near future. These experts believe, that involving 3rd Party Developers “would yield a 30% total system development cost reduction or approximately a 50% savings in the software development” [1].

ADVANTAGES FOR CAR SPECIFIC ADAPTION

The use of HTML5 allows a fine-grained adjustment to the target IVI system, because the separation of logic and design is strongly integrated in HTML. In order to automate platform-specific adoptions, we use a set of standard graphical user interface elements. For this reason, different style sheets for these elements need to be created only once for each new platform. This is a big advantage over other solutions because applications do not need to be individually tailored for every target IVI system in order to provide a platform specific look and feel. Additionally, a huge number of 3rd Party Developers is already familiar with HTML5. The development for HTML5 is comparatively simple, there are many existing tools and intermediate results can be tested in an ordinary Web Browser.

The utilized Web Application Framework allows for extensions by a plug-in concept. It is possible to adjust the framework to custom needs and extend and update it later on.

In order to deactivate features that are inappropriate while driving, HTML5 content and layout descriptions can be used directly. It is not necessary to provide additional metadata for adjustments.

SECURE EXECUTION OF FOREIGN APPLICATIONS

As described earlier, secure execution of 3rd party software in cars requires appropriate protection mechanisms. Using Web Technologies for applications and executing them in a Browser sandbox appears promising, as premium cars already provide Web Browsers. In our solution, access to local vehicle functions is currently protected by the browser sandbox and by a gateway we have in place for communication with underlying vehicle hardware. While our research prototype does not contain any mechanisms to authenticate and authorize devices and applications, we agree that a productive implementation should include mechanisms to only execute tested and approved applications.

ENSURING DRIVER SAFETY

Providing driver safety is a lot more complicated for 3rd party applications than for native IVI functions. Currently, the implication of certain HMI characteristics to driver distraction is a matter of research [12], [13]. For this reason, and because of individually different driver behavior, it is impossible at the moment to predict the imposed level of driver distraction just by analyzing the components of an application. Only empirical measurements allow for rough estimations [13]. Unfortunately, quality tests like driving simulations are unsuitable for the majority of 3rd Party Developers because they are complex, time consuming and costly as they require special equipment. While final testing and approval should be up to automotive experts, some preliminary measurement tasks should be passed to 3rd Party Developers. As quality control is an iterative process, this would speed up the deployment process. Therefore, we believe that it is necessary to provide concrete checklists and distraction measurement tools with a software development kit. 3rd Party Developers should be able to apply these preliminary measurements without additional hardware.

To further improve driver safety, workload managers might be included in IVI systems [13] [14]. Locally executed high-level applications are well-suited for such concepts because they allow for sophisticated control at runtime. With workload managers in place, it might be possible to prioritize and schedule interactions not only of native IVI applications but also those of foreign 3rd party applications.

CONCLUSION

In this position paper, we presented arguments for a Web Technology based middleware that allows for fine-grained integration of mobile devices into cars. Firstly, we presented alternative solutions and possible counter arguments. Then we described in detail the benefits of an open and standardized high-level middleware platform. By utilizing such a platform, OEMs would benefit from a broader support by 3rd Party Developers and from a high compatibility to existing mobile platforms. 3rd Party Developers would benefit from commonly known development practices and existing tools.

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Unmuting Smart Phones in Cars: getting phones to speak to us in ways their owners can't

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ABSTRACT
In this position paper, we argue that as a first step in directing experience development for features and services that will span both built-in IVI systems and internet-connected devices that drivers and passengers regularly move in and out of their cars, we need to understand how people conceptualize time, routines, and activities enabled by automobility. We need to understand how these experiences are being challenged and remade by smart phone use in cars. We describe our ongoing efforts in the Local Experience of Automobility (LEAM) Project to delineate how, when, where and why people interact with their smart phones during and around car journeys, through a combination of methods to track and probe on smart phone use in cars among drivers who regularly use their smart phones while driving.

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

General Terms
Automobility, ethnographic research, sensors, GPS,

Keywords
Ethnography, GPS, Smartphone use tracking, IVI , automobility

1. INTRODUCTION

The future of in-vehicle digital experiences will be a mix of built-in and brought in technologies such as navigation systems, entertainment systems, radar detectors, smart phones and tablets. This technology heterogeneous future is consistent with the heterogeneous present, and is predicated on incommensurate consumer-driven refresh cycles for automobiles (ideally 3 years in Singapore, for example, and more along the lines of 7 years in the US) and smart phones (as frequently as every 6 months in some markets) that is acutely felt by both OEMs and by car owners and users, and unlikely to fundamentally change in the foreseeable future.

AutomotiveUI'11, November 29-December 2, 2011, Salzburg, Austria.

The technology heterogeneous present encompasses a continuum of methods for bringing content and services into the car, models for interfacing and interacting with them, and sources of compute power that drive these experiences. In cars without the latest and most advanced IVI systems, we see a patchwork of methods for integrating peripheral devices to existing car infrastructures, from electrical power to audio systems to visual displays. At one end the continuum are IVI systems that only allow content to be brought in via SD cards or USB keys, relegating all the intelligence and interaction to the in-car system. On the other extreme are systems that allow wired or wireless syncing and interaction with content and services from the brought-in device through a variety of modalities such as: touching an IVI screen, pressing buttons, twisting knobs or speaking to a voice-driven system.

In this continuum, what we find most interesting are the tensions inherent in what we think of as the messy and contentious midpoint - an experience area we define as encompassing both solutions for connecting smart phones to the infrastructure of the car that keep the interaction and 'smarts' on the phone itself, as well as continued use of smart phones not connected or synced to the car at all, even when such solutions exist or could relatively easily be added to the vehicle. These practices belie many car users' great ambivalence about how new communications, information and entertainment options are integrated into cars. As mentioned in our poster on the Car Turn Outs project [1], Reggie, a design director in London who regularly uses his Smartphone to listen to music while driving, epitomizes this ambivalence. While he recognized that "my car takes me back 10 years", he was unwilling to do away with his CD player in favor of an IVI system or even a stereo with USB or memory card slot because it wasn't worth investing in a technology that he couldn't take with him outside his car. His preferred solution was to listen to his music on his iPhone, with the sound turned to high volume.

We want to better understand users' ambivalence to investing in integrating smart phones with in-car systems in order to scope future safety, communication, entertainment and other digital experiences for smart transportation. We start with two assumptions: first, that intelligence and services will be distributed across platforms ("built in" and "brought in)", and second, that such experiences should be responsive and customized to various automobility experiences around the world.

As a first step, we believe that we need to understand with a fair amount of specificity exactly what people are doing – and not doing - on their smart phones while in their cars.

2. SPECIFYING "SOMETIMES" and "IT DEPENDS"

Over the course of the past year, we have interviewed car owners in the US, UK, Singapore, Malaysia, China, Australia, Italy, Brazil and Germany. As part of these interviews, we have asked car owners to systematically empty the contents of their cars and explain why various items – from *ang pau* envelopes to shopping cart tokens to handguns – are in their cars. While we've found this exercise a useful way to elicit information on important activities, routines, and social relationships that take place in/with/through/ around/ because of the car[1], we've found smart phones to be frustratingly opaque and mute artifacts. Many of these drivers admitted to using their smart phones during and adjacent to their routine car journeys, and their descriptions of their behavior were maddeningly vague. While some were sheepish about admitting to even touching their phones while driving and others bragged about their multi-tasking skills, almost all descriptions they gave of what they were actually doing on and with their phones were generic ("I make calls", "I browse", "I look at maps") and took place in hazily defined locations ("while I'm driving", 'while I'm going slow") and in a temporal frequencies ("sometimes", "it depends").

In our current study, Local Experiences of Automobility (LEAM), we are exploring the heterogeneity of automobility futures through classic anthropological and ethnographic methods combining disparate data types and analyses in service of multi-faceted portraits of automobility in Brazil, Germany, China, Russia and the US. Our methods address the fundamental ethnographic imperative to understand and reconcile the differences among what people say they do ("I browse . . . while I'm going slow . . . . sometimes") and their actual behavior. We want to know not just what they think they are doing, and what their actual behaviors indicate, but most importantly how they make sense of their actions when provided with information about their behaviors over time. We want to transform our understanding of smart phone use in cars from a quite limited questioning of opaque and mute artifacts to a rich conversation with research participants about transparent and voluble artifacts they use in their cars.

Research participants in the LEAM project are limited to car owners who have bought a new car within the last three years that has some level of OEM or aftermarket entertainment or communication technology regularly used (ranging from stereo system with USB or Smartphone connectivity, to DVD players, to aftermarket GPS). All participants also regularly use their smart phones while in their car – at least 3-5 times a week for at least one feature or activity beyond making or receiving phone calls.

While the LEAM research includes a broader range of methods, here we will focus on how we are exploring the interplay/tension between built-in and brought in technologies. After initial in-depth, in car/in home interviews, we outfit participants' cars with passive GPS devices that track their cars' routes, stops and speeds for one month and install an application on their smart phones that allows us to track how they are using their phones during this same period. The application, called the Program Utility Manager (or PUM) Tool, was developed by Intel researchers and has so far mostly been used in large panel studies of mobile phone and PC use [2]. In the LEAM project, the PUM Tool allows us to track when participants use their smart phones. Specifically, it allows us to track the state of the smart phone at 10 second intervals (the state of the screen, orientation, 3-axis accelerometer) and the current focal app (Facebook, What's Up?, Maps) or feature (text, phone call, etc.) at 50 second intervals. For privacy reasons, we do not have access to any phone numbers or website names that are used on the phone.

To make phones speak to us in ways their owners can't, we analyzed phone usage for fifteen minutes before, continuously during and for fifteen minutes after each car journey, as defined by GPS data. We chose this time cushion around car journeys based on initial ethnographic interviews with drivers who mentioned activities done on their phones in preparation for a trip (looking up an address or getting directions), and at the conclusion of a trip (activities that cannot be done during the trip for any reason they defined (frequently mentioned were checking and or sending email or text messages). Synchronizing time-stamped GPS data (location, route, speed) with time-stamped PUM Tool data (feature or app name), gave us detailed behavioral data about in-vehicle smart phone use.

With this data we have created a series of visualizations of automobility routines that we share with participants to facilitate a discussion about phone use, car use and their overlap. While the tracking isn't perfect (was the person in the car for a particular trip? was the GPS perfectly aligned to the second with the PUM data?), the combination of tracking and interviews provides a rich set of data for exploring the messy middle ground of brought in/built in technology use.

As this conference takes place, we have just finished our research in Brazil and have GPS and Smartphone tracking ongoing in Germany. We do not yet have a definitive set of recommendations or findings. We are experimenting with the most effective ways to visualize the data to optimize discussion with participants. Currently we are working with two approaches.

1. Privileging routes and geographic location through Google-Earth powered maps showing routes and speeds with pushpins to indicate the location of smart phone use. We can visualize anywhere from a single journey to an entire month of journeys at once.
2. Privileging times and schedules through timeline of car use and app use over a series of single days.

Each visualization lets us investigate different aspects of the intersection of automobility and smart phone use. The maps, in particularly, are proving valuable in exploring the dynamic relationships and the reciprocal influences between smart phone use and the various transportation landscapes as the car moves through places, both displaced and intimately connected to its physical (and legal, cultural, regulatory . .) environments. Our initial engagement with our data has us thinking about how the experience of mobility is being recursively reconstituted through the presence and use of internet and telecommunications service connected smart phones that are also concentrated archives of rich multi-media content. Ultimately our visualizations and our data are a means to address more basic questions around how people conceptualize time, routines, environments and activities enabled by automobility, and how these experiences are in flux with the addition of new smart devices and services into the car in the form of smart phones and other digital devices.

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