Applying the User-Centered Design Process to External Car Displays

Kai Hollaender[1 1]

Medieainformatics, LMU[1]

kai.hollaender@ifi.lmu.de

Abstract

Semi-automated and autonomous cars create new use cases for external displays. Such displays have the potential to provide information about the intentions of an autonomously moving vehicle or indicate the car's status (manual vs. automated driving). A major challenge is that in-situ studies for evaluating external car displays are not possible yet, since as of now, cars featuring complex external displays are not established on public roads. Autonomous driving prototypes are costly and could provoke risky situations in the wild. Hence, a well thought out design is important. The user-centered design process seems to be a suitable methodology to achieve high usability. This HCI-tool proofed effectiveness in other research areas and could provide valuable contributions towards the development of external car displays. However, in order to use the process it needs to be applied to the context specific challenges. Open research questions are (1) identifying users' needs and goals regarding external car displays and (2) developing an user-centered, design based toolkit to satisfy those. This paper aims at indicating open challenges as well as possible solutions. Presented research opportunities and suggestions are meant to be discussed within a workshop. The long-term goal is to acquire best practices for researchers and practitioners in order to develop safe and usable applications for external car displays.

1 Motivation

The automotive sector faces groundbreaking changes. Currently, the degree of automation increases from manual to semi-automated and eventually autonomous driving (Litman, 2018). As a result, drivers can engage in activities which do not require them to observe their surroundings (Pfleging et al., 2016). Hence, driver-to-pedestrian communication might not be possible in every situation and should therefore be replaced by vehicle-to-pedestrian concepts. Moreover, automobile manufacturers increasingly focus on developing electric motors and include advanced sensory and computing power in their products (Luettel et al., 2012). Thus, it could be valuable if cars display their driving range. Additionally, vehicles might be able to gather information which could be included in smart-city concepts besides a traffic-related context. For example, indicating environment conditions like air pollution to passers-by.

Automobiles seem to evolve from a personal status symbol to a practice-based community object (Barth and Shaheen, 2002; Litman, 2018). Future cars might represent public transport units rather than private property. Shared vehicles could display personalized welcome messages for every passenger. Hence, viewing cars as interactive ubiquitous computing systems offers new possibilities for interaction applications on their surfaces. Additionally, External Car Displays (ECDs) on the chassis could be used to personalize the look of a car.

Furthermore, trust is a crucial aspect for acceptance of new technologies such as autonomous driving (Creech et al., 2017; Lee and Song, 2013). However, Yan et. al successfully performed various attacks on a Tesla Model S vehicle (Yan et al., 2016). The technical implementations of modern vehicles presumably remain vulnerable. ECDs might contribute to enhance safety and thereby support the development of trust. For example, such displays could indicate intended actions of an autonomous vehicle to pedestrians or cyclists. Thus, they might raise awareness and avoid collisions.

ECDs provide a possibility for passengers to interact with their surroundings. Street vendors approaching a vehicle could become informed via an ECD about the occupants' interest in an offer (e.g. a bottle of water). Additionally, such displays might support hedonic quality. For example, by showing personalized emoticons to pedestrians.

Since using complex dynamic external displays to interact with the surroundings of vehicles is a novel approach, there are neither established design nor evaluation tools for such displays, yet. Besides manifold advantages, ECDs might become an additional source of distraction, especially if they are ubiquitous in urban environments. This work aims to present a foundation for implementing the user centered design process to ECDs and spark a discussion about how to develop safe and usable applications for future external displays on vehicles.

2 Related Work

Rothenbücher et al. explored how pedestrians behave if they face an autonomous vehicle without a driver (2016).They come to the conclusion that pedestrians benefit from a display confirming their recognition. Häuslschmid et al. presented a design space about windshield displays (2016).They address windshield applications for occupants of a car as well as passers-by. Colley et al. introduced a design space regarding ECDs (2017)Findings from these design spaces were an inspiration for many use-cases mentioned in this work. Furthermore, Colley et al. investigated multiple use-cases for external displays and contents projected onto the surface of vehicles (2018).According to the authors, information about car or driving related functions (parking, warnings for pedestrians) and adjusting aesthetics via an outside display seem attractive to users. Alt et al. investigated if ECDs could be used to display advertising by conducting an online survey (2009). Half of the participants stated that they would accept advertisements on their cars as long as they could select them and receive financial compensation. Fridman et al. compared a total of 30 vehicle-to-pedestrian display concepts, including low resolution and high-fidelity prototypes (2017). They suggest to use MTurk for evaluating early stage designs (Amazon Mechanical Turk Inc., 2018).

Some automobile manufacturers include ECDs in current prototypes. For example, the Mercedes-Benz F015[1] is able to project a crosswalk on the ground. Semcon[2] developed a concept-car which is capable of smiling to pedestrians. A smile is used to communicate that it is safe to cross the road in front of the autonomous vehicle. Smart follows a similar idea. Their concept "Smart Vision EQ Fortwo"[3] can wink with its front lights and features an additional ECD at the radiator grill for displaying text.

3 Applying the User-Centered Design Process

The goal of User-Centered Design (UCD) is to generate solutions with a high usability. UCD describes an iterative process with four main stages: (1) analysis of usage context, (2) identification of design requirements, (3) evaluation and (4) implementation (Abras et al., 2004; Norman and Draper, 1986). Unlike system-centered design, UCD involves user feedback throughout all iterations and development phases (Mao et al., 2005). Goal-directed design by Cooper and activity-centered design by Norman could be employed as methodology for developing ECDs, too (Cooper et al., 2014; Norman, 2005). However, all of the mentioned approaches require understanding users' tasks, goals and behavior as well as considering usage context. The following subsections indicate how UCD could be implemented in regards to ECDs.

3.1 Analysis of Usage Context

Personas could be valuable for identifying the user group. In the context of ECDs they should include drivers, passengers, handicapped people, pedestrians and cyclists of all ages.
The following list briefly describes possible scenarios and use cases. The first sentence could be transferred into a scenario or user story whereas the second sentence includes a rather specific use case.

- Cars with different levels of automation share the road. Autonomous driving cars indicate braking, acceleration, lane and directional changes towards other road users.
- Platooning cars, modular vehicles and drones share a public space. ECDs could display occluded objects, detaching platooning cars or vacant segments of a modular vehicle.
- There are autonomous cars only. ECD could be used to send out visual cues which avoid collisions with animals, e.g. deer or kangaroos.

[1] www.mercedes.com/en/mercedes-benz/innovation/research-vehicle-f-015-luxury-in-motion, retrieved June 2018
[2] www.semcon.com/smilingcar/, retrieved June 2018
[3] www.daimler.com/innovation/specials/iaa-2017/smart-vision-eq-2.html, retrieved June 2018

3.2 Design Requirements

Non-functional requirements describe quality goals for a system. In context of ECDs they demand comprehensibility and ease of use, especially for people with a lack of language skills, color blindness and other limitations. Furthermore, ECDs should be visible during the day and not blind in darkness. They are supposed to respect users' privacy, even if a number of people is watching the display. Aesthetic features should be supported, too.
Functional requirements describe aspects which need to be implemented. For ECDs that could be: adaptive brightness according to surrounding light conditions, controlled by a light sensor, web-interfaces to provide news, sport results or other third-party services. Additionally, appearance and content of such displays could be personalized via external devices (smartphone, tablet, computer) or with an in-vehicle infotainment system. Hence, connectivity with an application programming interface is a functional requirement.

3.3 Evaluation

Evaluation is essential for an iterative development process. Evaluated results lead to a reconsideration of the prior steps. Additionally, they refine the understanding of user-behavior and the effectiveness of a concept. Open challenges are: Where do users look? Do they use the system as intended by the developer? How often/intensely do they need support while using the system? Do they enjoy using the prototype? Do they feel the concept provides a valuable contribution? Hence, the general goal of this UCD-phase is to gain insights in the degree of UX and usability.
In context of ECDs an impact of the design on acceptance, trust and perceived security should be measured. It is important to gain valid information about the concept's influence on perceived safety and usability in traffic situations.
Possible human-computer interaction tools to investigate mentioned attributes in regards to ECDs could be: questionnaires, surveys, prototype-studies (e.g. by simulating an ECD with a projector, virtual reality, Wizard-of-Oz, images or paper only), eye-tracking (for monitoring gaze behavior) and interviews.

3.4 Implementation

If a prototype was successfully tested against the requirements, it can be fully implemented. However, regarding this work there are many unsolved challenges in context of the prior stages. At this point, it is still too early to design a high-fidelity prototype, as we have neither sufficiently analyzed the usage context nor did we identify all requirements, yet.

4 Discussion

An adjusted user-centered design approach could support researchers and practitioners to identify potential improvements and to quantify the quality of ECDs. However, the identification of User Experience (UX) goals, users' requirements, needs and behavior regarding ECDs remains an open challenge. Related research questions could be: Which information is when presented and how? Furthermore, a classification of ECD use cases in context of e.g. surroundings (highway or city, weather conditions, autonomous cars only or manual and automated cars mixed), level of automation (SAE level 0 to 5), kind of travel (platooning, modular cars, fixed roads or shared spaces), culture (language or temper), personal preferences (appearance, sentiment, emotions), kind of task (social interaction, safety related, fun) and type of car (private, shared or public) could be investigated.

Suitable questions for a focused discussion might be:

- What are possible applications of ECD?
- Is UCD a suitable approach for designing ECDs or are there better solutions?
- If ECDs are utilized beyond traffic safety, how can users distinguish relevance of displayed information?
- How to best quantify the benefit and value of an ECD application?

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