Car Exterior Surface Displays: An In-the-Wild Evaluation

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ABSTRACT

Current changes in the automotive industry towards autonomous vehicles will spur wide ranging changes in the roles of cars in urban environments. When combined with advances in display technology, this creates potential for the outer surfaces of cars to act as public displays. We present an in-the-wild study, where participants ideated on a variety of different types of informative content, displayed on or around vehicles. Our study approach utilized handheld projection to create visualization experiences suggestive of the capabilities of future display technologies. The salient findings show that ideas related to the car and the driving function, such as parking, warning pedestrians and changing the vehicles aesthetic appearance, were appreciated. In contrast, ideas where the vehicle formed part of a smart urban infrastructure, such as guiding pedestrians or acting as a public display caused diverse opinions. In particular, concepts where personalized content was shown were disliked for reasons related to privacy and feeling like 'big brother' is watching.

Author Keywords

Automotive UI; public displays; interactive surfaces; pedestrian guidance; pervasive navigation; spatial augmented reality; projected AR.

ACM Classification Keywords

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

INTRODUCTION

Throughout their evolution, cars have been platforms for a variety of different kinds of interactive technologies. In recent years, research has addressed topics such as car dashboard design [6,7], different input methods for in-car touch screens [11], persuasive UI design for more economic driving behavior [24], and haptic feedback for interaction [17, 32]. To date, the vast majority of car related interaction research has focused on cars as a means of transport. However, with the development of cars to become artificially intelligent robots, equipped with huge numbers of sensors and processing capacity, it is timely to consider cars in a wider role than simply transporting their occupants.

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Figure 1. Car external surface display concepts included in the focus group study. The displays are created using a handheld projector. 1) Navigation guidance for pedestrians or other (car) drivers 2) Warning for pedestrians/other car drivers of car reversing. 3&4) Warning for pedestrians or other car drivers of other vehicles moving.

Nowadays, cars form a ubiquitous part of the visual urban landscape, with many cities literally being choked with vehicles. Thus, when considering future smart cities, cars should be considered as an integral part of the infrastructure. This direction will be further supported by the predicted moves towards cars becoming shared resources and reduction in individual car ownership. In this paper, we consider the outward visual appearance of cars and explore the potential to use them as platforms for external displays. Due to the rapid development of display technologies, the technical enablers for this approach are becoming potential in the near future.

This direction presents a variety of potential use cases, such as parked cars providing information to pedestrians and other drivers, which go beyond (static) advertisements as we see it on some of today's cars. The outer surfaces of the parked vehicles could visually inform drivers and pedestrians of each other, thus enhancing pedestrian safety. Alternatively, parked cars could form part of a pedestrian navigation system, with the cars' surfaces displaying guidance information, thanks to Intelligent vehicular ad hoc networks (InVANETs).

Similarly, for other drivers, parked cars could visually provide directions to the nearest free parking place. Once a parking place is located, the neighboring cars could guide the parking maneuver by visual indications.

When in motion, or about to move, the outer surfaces of cars can communicate information to other drivers and pedestrians. This is particularly important in the case of driverless or semi-autonomous vehicles, where the lack of a human driver to communicate with the surroundings must be replaced with externally visible displays. This has been explored in the Mercedes F105 [35] and the 'smiling car' concept [34]. Other potential use cases include content display on the vehicle's surfaces, e.g., information on vehicle status or performance. As a behavior change tool, cars could externally display their actual fuel economy and environmental footprint.

As a contribution we present, to the best of our knowledge, the first in-the-wild evaluation, exploring the potential for the exterior surfaces of cars to act as public displays. This work is timely, due to the current wave of change impacting the automotive domain. The transformation from driver-centric experiences to autonomous vehicles will potentially transform the car into a shared resource, with its computing, sensing and output capabilities being integrated into the fabric of smart cities. With our work, we present insights on how the automobile may evolve to support new functionalities.

RELATED WORK

Whilst there is a very large body of work on public displays in general, the works most relevant to our topic come from the segments focusing on public displays for navigation purposes and mobile public displays. Considering our automotive context, we also review prior research looking at displays visible from the outside of cars and note the relevance of ethical questions pertaining to autonomous vehicles.

Mobile Public Displays

When mobile public displays are considered, the dominant approach to such displays has been through the use of flying drones, either to carry a display screen [29] or projector [28]. Public displays created with projectors have been demonstrated both on stable objects, such as houses, and on moving surfaces [28]. An interesting variant of a mobile public display in the aquatic domain is Ukai and Rekimoto's Swimoid, a mobile display following swimmers underwater [31].

Wearable forms of displays that show the content towards the public have also been presented in wide numbers. For example, clothes integrated public displays, e.g., displaying heartbeat [30], information when jogging [23], and the ambient noise level [26]. Works on public displays integrated to different accessories include, e.g., handbags [10], backpacks [1], and neck-worn badges [15]. Also, constant personal projection has been suggested [33].

Public Displays for Navigation

In the context of traffic and mobility, wayfinding is a central use case. Utilizing public displays for navigation has been suggested in several studies. The use of dispersed public displays for pervasive pedestrian navigation has been studied by Kray et al. in their GAUDI system [19]. Here, additional signs may be dynamically placed and the system automatically reconfigures the signage displays to present the optimal navigation route. The addition of animation between consecutive displays was investigated by Coenen et al. [9].

Issues concerning the display of personal information on public displays, such as a navigation route, have also been a topic for research. For example, Kurdyukova et al. [21] reported on trust-critical issues. One approach to maintain privacy when personal navigation information is shown on public displays is demonstrated in Rukzio et al.'s rotating compass, where an on-body vibration signal indicates the moment that the display indicates relevant information [27].

Displays that are projected in the close proximity of the user, and hence potentially publicly visible, have also been demonstrated in the navigation context. Dancu et al. have presented a projected display for cyclists, where the map is projected on the ground in front of the bike [13]. Winkler et al. present a similar prototype for pedestrian use, and for a larger selection of content and use cases [33].

Car Surfaces as Visual Output Spaces

Traditional Car Surface Visualization

Traditionally, cars have a variety of output mechanisms on their outer surfaces, in the form of vehicle lights to inform others of the vehicle's intention to turn, overtake, brake or reverse. In addition, other static or semi-static indications are visible from outside the car, including license plates, stickers advertising the car dealership from which the car was purchased or other companies, as well as personal customization such as bumper stickers, sunshade strips and various other adhesive decals.

In traditional human-driven cars, the driver and passengers also contribute to the visual output space of the car, e.g., providing eye-contact and hand gesture signaling to pedestrians and other car drivers through the vehicle's windows. With the move towards autonomy, likely this aspect of output will be diminished with vehicle occupants paying less attention to events outside the car, and new car designs potentially reducing support for this channel.

Contemporary Research

The car *dashboard* has been the main scope for research on displays in the automotive domain, e.g., [7, 18, 20]. Novel solutions such as heads-up and head-down displays [16] and stereoscopic displays [1] have been reported. Whilst ambient information displays, operating in the periphery of the driver's attention [22], have been demonstrated in various domains to display, e.g., energy consumption, navigation cues, or social network activity [25], they have not so far been explored in the context of external car surfaces.

Regarding the use of *exterior* surfaces of cars, Alt et al. investigated the users' view towards sharing these surfaces as advertising space [2]. They found that users are willing to do so but want to stay in control of the shown content. Furthermore, design spaces for the exterior surfaces of cars have been presented by Haeuslschmid et al. [14] and Colley et al. [12], the former focusing on the windshield space. Taking these works as a starting point, we explore the potential of the design space though representative prototypes evaluated through an in-the-wild user study.

Autonomous Vehicles and Ethics

When addressing the topic of cars and autonomous vehicles, safety related issues are important. When investigating car surfaces as displays, the viewpoint becomes important both from the targeted use cases as well as from the traffic distraction point of view. There has been much recent discussion considering the ethics surrounding autonomous vehicles, e.g., [5], which has largely focused on crash scenarios, e.g., choosing between the safety of passengers and pedestrians. However, we were unable to find works exploring the potential for static autonomous vehicles to play a role in the safety of nearby pedestrians, e.g., by warning of oncoming traffic.

USER EVALUATION

To investigate perceptions on the topic of car surfaces as public displays, we created a prototype using a handheld projector and a set of example content to be displayed on the car surface (Figure 1). This was then evaluated through two focus group sessions. This approach enabled us to explore the concept in a real world context.

Method

Different display content was used as a stimulus. Based on the range of content types presented by Colley et al. [12], the following content images were created (see Figure 2):

- Placeholder shapes – square and star, to support unguided participant ideation
- Navigation arrows
- Pollution / Fuel consumption
- Forgotten keys & phone message
- Social media post
- Advertisement
- Aesthetics, e.g., fire decal, bumper sticker mottos
- Warnings, e.g., informing a pedestrian of another nearby car moving

To evaluate the concepts, two focus groups were arranged (Figure 3). The focus groups took place in a public car park. Content examples were projected in turn onto different areas of vehicles and participants were encouraged to think-aloud and discuss their views and opinions on each. Participants were told to imagine a future technology where the outer surface of cars could be dynamically changed. For the purpose of the study this being simulated by projection. In each case, the test moderator guided the participants to think from the car driver's, other car drivers', cyclists' and pedestrians' points of view. Issues related to autonomous or shared cars were also probed by the moderator.

Figure 2. The set of probe images projected onto car outer surfaces or on the ground around the car. See Figures 1, 3 and 4 for example projected contexts.

Eight study participants were recruited from the University of Lapland's pool of user study volunteers. The participants were divided into two focus groups, each of 4 persons. The mean age of the participants was 27 years (*SD* = 3 years), and half were female. Six held a full car driving license. For their daily commute, 5/8 mentioned using a car, 3/8 a bicycle and 3/8 walking (some mentioning multiple methods). Due to the (limited) seasonal daylight conditions in the study location during the tests, the visibility of the projections was good.

Results

Initial Ideas

To first explore participants' initial, unguided ideas about car surface displays, empty placeholder shapes were projected to the car's surface (Figure 3.1 & 3.2). In response to the rectangle placeholder, both groups mentioned advertisements. Other suggestions related to information that other drivers could use to improve safety, such as road conditions, the distance to the car in front, or a warning of driving too close. Other ideas focused on information about the driver's capabilities, e.g., blood alcohol level, state of mind (e.g., aggression level) and age (e.g., very young or old). One group discussed the display of information for pedestrians, such as if the car was about to move. The star shaped placeholder was seen as purely decorative.

Figure 3. Focus group study. 1&2) Initial brainstorming using empty projected shapes as probes. 3) Pedestrian navigation using arrows displayed on vehicle surfaces. 4) 'Forgotten keys' notification displayed on car door surface.

Parked Cars as Pedestrian Navigation Guides

When visual cues for pedestrian navigation were presented on the car's surface, the initial reaction of all the participants was suspicion. The idea was mentioned to feel creepy or uncomfortable, e.g., *"It feels like big brother is watching"* (Participant 3), and, *"I don't like the idea. I'd rather ask someone than search some signals."* (P5). Navigation information display on the car body was considered more uncomfortable than if it was projected on the ground. An example comment in this respect being, *"If it was projected on the ground or somewhere else, it would be OK. That's just really creepy [when the arrows are on the car body surface]" (P3).* However, all the participants considered the guidance arrows easy to notice. Still, they questioned how they would identify that the navigation signals were for them, e.g., commenting, *"And you would feel like, is that [navigation sign] for me, or is it for the guy next to me, and is it navigating towards X or Y or…"* (P2). This also raised questions about privacy, e.g., *"Someone could start to follow you."* (P6) and *"The cars shouldn't remember [the information after displaying the navigation sign] - 'Today I helped Nina to find the abortion clinic'"* (P7). Concern was also noted from the car owner's view, *"On the other hand it would be really scary that my car, when it was parked and I was away, it would communicate and bling to all other people and would do all kinds of funny things when I was away, that would be like 'what the hell'"* (#8).

Parked Cars Helping to Find a Parking Space

All participants considered parking space related information as a very practical solution. It was not considered creepy or uncomfortable, because the information was not targeted to a particular individual, e.g., *"The information is available for everyone"* (P1). Participants thought the use of arrow-based visualization for finding a parking place was suitable, but also ideated on other approaches, e.g., *"If the cars were color coded so that the more space there was the greener the cars were"* (P6). Both focus groups suggested ideas related to parking rules, e.g. that the cars could indicate the allowed *parking time on the side of the car and automatically tell the police if they've been parked too long, or that the car surface would indicate to the driver if it was parked incorrectly.*

Figure 4. Car external surface display concepts. 1&2) Warning driver of forgotten keys. 3) Real-time environmental information. 4) Dynamic advert (e.g. dependent on parking location). 5) Changeable aesthetic surface patterning. 6) Driver's social media post displayed on car surface.

Displaying Vehicle Environmental Impact

Only one participant thought positively about the idea of showing the actual vehicle fuel consumption or pollution output, stating, *"You'd know how environmentally friendly the cars are compared to other cars' consumption*" (P8). In general, others stated they would not like to share information on their own environmental impact, e.g. *"[One could think that] the neighbour is consuming horribly much natural resources, what an asshole! I wouldn't like information about me to be shown like that"* (P1). However, both groups suggested that the feature would be useful when buying a car. Whilst the participants thought displaying the real-time environmental impact of the car would work as a marketing campaign, they did not believe it would encourage manufacturers or car buyers towards more environmental cars. Here a participant commented: *"Of course I'd try to buy the most environmentally friendly car, but it doesn't matter at all if others see it or not. They can already find the information from the Internet"* (P6).

Other Content

The idea of a message informing of keys being left in the car was liked by all participants, with the windscreen and projected on the ground when the door was open being preferred locations. However, this also raised safety concerns e.g., *"Some thief could see that there's a phone in the car"* (P8). Displaying social media profile or messages and advertising were universally disliked, e.g., considering displaying a Facebook profile on the car's surface *"That's unnecessary, excessive information, like is it needed."* (P6). Particularly, participants feared targeted advertisements, e.g., *"Feels uncomfortable, like if people inside the car were talking about something and the car would show an ad about it, so others could see what the people inside were talking about"* (P8). Benefiting from the potential for location-based advertising signage was also predominantly disliked, with participants preferring other methods, e.g., *"I'd rather search from my phone."* (P3). However, ideas related to personalization of the car's visual appearance were appreciated, e.g., *"I could use this during Halloween and Christmas"* (P2) and *"Like changing the background picture of your phone you could change the surface of the car"* (P6).

Improving Safety

Concepts to improve the safety of those around the vehicle were much liked, e.g., *"... you can't always see well when you reverse. And the reversing car could show some signal"* (P8). Similarly, a participant suggested that a car stopped at a crosswalk could warn the pedestrian crossing the road if other vehicles approaching presented a danger, *"When you start to cross a pedestrian crossing [and a second car comes], there could be some crazy alarm lights saying 'You will be run over soon'"* (#1). The preferred form of communicating danger was through projection on the ground, with a participant commenting *"The information should be shown clearly separated from the car"* (P8).

Safety assistance for vehicle drivers was also positively commented, for example, warnings about pedestrians or animals on the road, e.g., *"It would be really good if the car could highlight the pedestrians in the dark… "*(P3). Issues around information overload for the driver were also discussed, with iconic visualization being preferred to text, e.g., *"There could be a text in addition, but rather a big icon"* (P1).

DISCUSSION

Participants accepted use cases that were directly related to their current driving experiences, such as safety issues and parking. In contrast, concepts that extended the car's role, such as providing pedestrian guidance or located signage were less appreciated. Our results identify safety, privacy and self-image as underlying contributors.

Pedestrian and Driver Safety

Clearly, our participants found value in the potential of car exterior display solutions to contribute to overall safety in and around vehicles. This links to the safety criticalness of the domain. When the utilitarian value of a feature is clear, this positively affects the social acceptability of the feature.

Privacy Concerns

The study highlighted challenges with information privacy from multiple angles. The general concern of displaying information targeted for a particular individual on a publicly visible display was raised. For example, to guide a pedestrian or when searching for a car parking space. This issue has also been a topic in works on traditional public displays, with typical solutions being to utilize the public display in conjunction with a personal device, such as a smartphone [27] or by making sure that bystanders cannot observe the displayed information [8]. This suggests that future work could look into approaches that take into account both the users' current field of view or the direction in which they are looking (cf. [3]) as well as people in the vicinity to decide whether, where, and when to show such personal, targeted information. As an alternative method, it could be interesting to show such information in an ambient manner such that it could be understood by the actual user but not by other people around.

However, some participant comments suggested that the issues are deeper than the display, with the concept of being watched by autonomous vehicles when walking through a city evoking feelings of 'big brother' watching. We acknowledge that these findings may be partially a result of the employed methodology and simulated situation. For example, the benefit of a car display guiding a frustrated driver to an empty parking space may not have been obvious in the casual situation of the focus group. Examples from other domains show that indeed people are willing to give up on privacy in return for even small benefits (e.g., shopper loyalty cards, etc.) – so it may be worthwhile to investigate this further in the future.

Whilst participants were able to justify knowing information about other car drivers on the grounds of safety, e.g., blood alcohol level, they were uncomfortable about displaying even basic information about themselves when driving.

Car as Extension of Self

People's attachment to their cars is well known, e.g., Belk reporting that some individuals feel damage to their car as if to their own body, the car becoming an extension to their self [4]. With this background, the findings that our participants favored decorative additions to the car's surface was not surprising. Whilst on the other hand, other uses of the display surface, such as advertisements, which implied that it was a public resource and not owned by the car driver, were rejected. This resonates with findings from other personal/public display cases such as Colley et al.'s smart handbag [10]. The case of display of environmental impact information is of particular interest - whilst participants were happy that functional warnings for pedestrians were displayed, they were not willing for information reflecting on their purchase choices or driving behavior to be shown. Some similarity may be drawn with works looking at in-car guidance on economic driving [24], which reported that users did not like solutions that pressured behavior change. Surprisingly, in the case of display of safety related information, one participant required that this was shown separated from the vehicle, presumably to avoid any personal association with it.

Overall, participants' feedback in this area suggests lack of visibility or reluctance to accept the coming changes in the automotive industry towards shared-mobility solutions. This finding is also echoed by other sources, e.g., Mckinsey reporting that amongst US respondents 63% would not change their self-owned vehicles for shared-mobility solutions, even if they were free [36].

Methodological Notes

Our method of using a handheld projector in dusk conditions to simulate the potential of vehicle surface displays, worked well, delivering a strong perception of future solutions. The approach enabled us to present the solutions in an in-the-wild context, such that study participants could fully appreciate the practical issues related to the concepts. Whilst we are not the first to use this approach, we believe it is timely to revisit the use of handheld projectors as a display prototyping tool, given advances in projector performance and growth in use cases that suit the approach, e.g., flexible displays.

We acknowledge that, similarly to the global population of car users, our participants had little experience of autonomous vehicles and shared-mobility solutions, beyond the current taxi-like solutions. Thus, their comments reflected their current perceptions of cars as manually driven, private, and personally owned. We believe the direction towards driverless vehicles, reduced personal car ownership, and increases in custom-designed shared mobility solutions [36] forms the enabler (and driver) for new applications realized through car surface displays. We can speculate that this paradigm shift will have a similar impact to urban society e.g. as the introduction of smartphones just over a decade ago.

Future work on the topic should look into how concerns of users could be mitigated, for example by clearly communicating the benefits of such displays and providing means to provide information to the targeted person only. In addition, we see in many domains how the availability and use of novel products changes the user's attitude over time. Thus, a long-term study with an actual display hardware could investigate how such technology is accepted in real life.

CONCLUSIONS

Changes in the automobile industry towards artificially intelligent cars and the increase in shared mobility solutions, provide the potential for new applications, utilizing displays on exterior car surfaces. Based on a focus group study, solutions focusing on improving safety are considered as most beneficial. Use cases, such as pedestrian navigation, which display individually targeted information were disliked due to privacy concerns. The current generally held view of cars being an extension of the driver's self presents barriers to the utilization of cars as a functional display element in smart cities.

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