Contextual Inquiry of Future Commuting in Autonomous Cars

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Abstract
Millions of people consider their car-based commuting a daily hassle. Autonomous car technology promises a relief from driving related stress and may change the commuting experience fundamentally. So far, research in this field has mainly been focused on commuting in manually driven cars or on usability and safety issues of specific driver automation technologies. In order to explore how to design activities and entertainment for future commuting in fully autonomous cars, we conducted a contextual inquiry inspired field study with three car-based commuters in an improvised autonomous car. This paper introduces our research setup and presents preliminary findings. It contributes to the exploration of the design space of autonomous driving in two ways: (1) the paper describes a pragmatic approach to adapt a contextual inquiry for the exploration of future use cases of autonomous driving and (2) it also articulates design implications and temporal frames derived from our first set of user studies that we regard as essential for designing context-sensitive entertainment in future cars.

Author Keywords
Automotive User Experience; Autonomous Driving; Commuting Experiences; Contextual Inquiry.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Although user experience (UX) research of autonomous driving has gained a lot of attention in recent years [7], little research is available on how the everyday use of autonomous car technology will affect the user experience. Automated driving technology that takes over the driving task for a defined part of the trip is already available but require the driver's supervisory responsibility [12]. Experience research on related driving technology has shown that the new role of the driver may result in a feeling of reduced competency and autonomy [2]. In the near future, even the responsibility of the driving task may be transferred to the car. This transformation from a driver to a passenger may enable other much more demanding activities, such as gaming or working, while being driven by the car.

Daily commuting may be a promising use-case for automated driving. Studies on commuting show that car-based commuting is regarded as the most stressful commuting style [4]. Relieving a commuter from the driving task has the potential to transform their daily commute into a less stressful experience with unique entertainment or productivity opportunities. In order to gain insight into the commuting experience of the future, we conducted a field study inspired by the contextual inquiry method [3]. The goal of inquiry was to identify contexts as design sensitivities of commuting in autonomous cars. In doing so, three Melbourne-based car commuters have been observed and interviewed during their regular commutes within an improvised autonomous car service.

Related Work

Commuting has been studied from a variety of perspectives. For instance, early literature investigated commuting from a socio-economic [4] or psychological-wellbeing perspective [8] concluding that in particular car-based commuting can affect the commuter's health (as well as the environment through, for instance, air pollution). Researchers have also shown interest in emotional experiences of drivers or passengers. Thereby, a large variety of methods from surveys to cultural probing approaches, such as logging systems and driver diaries, have been adapted [5, 9].

In the context of driving automation, studies have been conducted to understand the emotional effects of losing operational control over the car emphasizing trust as a crucial UX factor [6, 11]. On a more general basis, researchers were interested in identifying the acceptance of first encounters of (semi-) autonomous technologies concluding that the popularity of such technologies are limited [10].

Recently, researchers have shown interest in studying the UX of autonomous driving in real world situations. To compensate for the lack of availability of fully autonomous cars, researchers have to depend on 'wizard- of-Oz' methods, such as visually isolating the driver from a front-seat passenger [1]. Contextual research dedicated to a defined use case, such as commuting in autonomous cars, has not been conducted so far.

Figure 1: Camera setup.

Figure 2: Arrangement of the footage as seen from both cameras.

Methods and Procedure

Crucial for conducting a contextual inquiry is a trustful relationship between the study participant in the use context and the investigating designer. However, in order to study a future situation, such as commuting in autonomous cars, we exposed the participants to a new contextual frame. Instead of creating a wizard-of-Oz setup, the investigating designer took on the driving task to simulate an autonomously driven commute. In that way, three Melbourne-based car commuters were driven to their workplace and back home on a usual workday. We assume that the passenger experience resembles the future everyday routine of commuting in fully-autonomous cars much more than a wizard-of-Oz approach. However, the substitution of driving through a passenger experience affected the usual commuting setting with various limitations that are being discussed later.

The commute was recorded with two cameras. Each camera was equipped with a wide angle lens. One camera recorded the participant in the car whilst the other camera recoded the traffic situation. The setup is illustrated in Figure 1. The arrangement of the video footage of the two cameras for the video analysis is depicted in Figure 2.

The passengers were instructed to respond to questions by the researcher as well as narrate their thoughts and feelings during the commute. In accordance with the contextual inquiry method, the researcher's role was to immerse them into the situation and lead the narration by asking questions regarding the relationship and structure of the commute. In addition, the participants were asked to make themselves comfortable in the car and to use all available devices such as the car's entertainment system or their own mobile devices as desired. The participants (Table 1) were recruited through word-of-mouth based on the following three criteria: (1) being a working professional with a regular day-time job, (2) requiring a car-based commute at least four times a week for more than a year, and (3) commute a distance of more than 20 minutes one way.

#	Occupation	Age	Sex	Since
1	Marketing Manager	28	F	2012
2	Architect	36	M	2011
3	Media Technician	39	M	2004

Table 1: Overview of participants and year since commuting.

Analysis

Based on our research question to identify design sensitivities and an initial viewing of the video material, four context criteria for further investigation have been identified: (1) traffic situation, (2) road type and environment, (3) activities and behavior, and (4) narrations and answers. The focus of the analysis was a subjective interpretation based on the investigators experience with the participants rather than a structured coding of video footage with the intention to predict and generate relevant design elements of a non-existent but simulated situation. The key moments of each commute were documented as a series of screenshots (Figure 3) with an annotation table based on the criteria (1-4) to support the analysis.

(1) Traffic Situation. The identification of the traffic situation was based on the camera directed on the road. In order to create an understanding of the traffic situation of each commute, we based this criterion on a

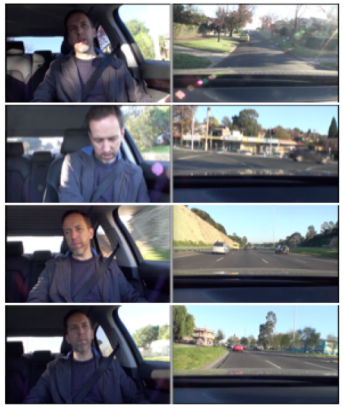

Figure 3: Screenshots of data analysis

simplified version of the Level-of-Service scale consisting of the four elements: (a) *Free Flow Traffic:* reaching maximum speed limit with no interruption by other traffic participants; (b) *Stable flow*: steady travel speed, but busy traffic; (c) *Stop & go*: very unstable traffic with many stops; (d) *Standstill*: standstill of the car for more than 30 seconds.

(2) Road Type and Environment. For the environment category, we defined four types of roads depending on the commuter's routes. (a) *Suburban roads,* i.e. roads and streets in primary residential areas. (b) *Highways*. (c) *Major city roads,* i.e. streets with at least two lanes serving as a link between city districts, (d) *city roads* with mixed residential and commercial buildings. Figure 3 shows a visual presentation of the participants' traffic and environmental contexts.

(3) Activities and Behavior. This category contained all activities and behaviors by the commuter besides the narration and comments. Typical activities included the adjustment of the radio or the use of their mobile phones. Of particular interest were shared behavior patterns that appear to structure, or at least influence, the commuter's activity in relation to the traffic flow.

(4) Narration, Comments and Answers. This category includes the verbal expressions of the commuter based on interview questions, the situational narration, and related comments. As narrations we subsumed personal anecdotes as well as expressions of the commuter's feelings. Most comments related to comparisons of past traffic experiences with the current traffic situation.

Interpretation and Preliminary Findings

Based on the annotation of the video footage, the researcher's own evaluation of the situation as well as the visualization of traffic and road types, we developed a tentative summary of design foci and contextual features that might inform the description of a design space of commuting in autonomous cars.

Experiential Context

(A) Work-Home Commute Disparity. Several commuter studies have shown that the work and the home commute are two very different situations. Not only regarding the emotional states of the commuter, but also in respect to the commuter's driving abilities and accident rates [4]. Indeed, the observation and narration of the three commuters align with these results. In particular, the home commute shows the tendency that the commuter is actively looking for social relatedness. Only on the home commute all three commuters were using their mobile device as a communication tool and reported that the commute serves as a time to plan the evening. In contrast, the work commute had a rather quiet and monotonous quality. This tendency suggests that the design focus of the work commute should be rather mentally stimulating, whereas on the home commute the focus should be on relatedness and communication activities.

(B) Environmental Suspension. Besides the work-home commute disparity, the commutes share a similar internal structure. This internal structure seems to be connected to the road type and the environmental factors of the commuter. The footage shows that often a new environment results in a change or break of a behavior or activity. For instance, entering the first unstable traffic flow on the home commute, the

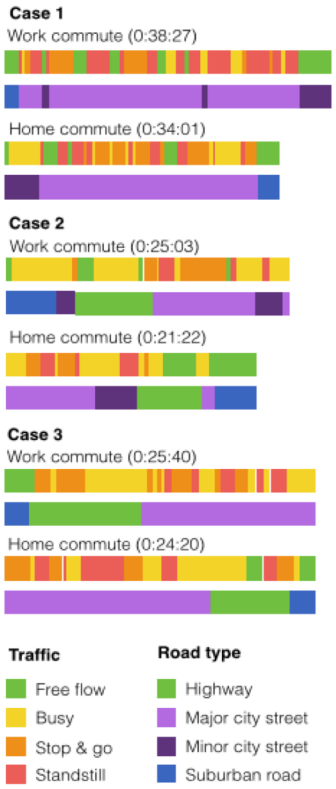

Figure 4: Summary of traffic situation (upper bar) and road type (lower bar) for each participant and each part of the commute.

participant pulls out a mobile phone. It appears as if the desire to connect to friends or family on the home commute is literarily triggered by the contextual situation of first traffic encounters. From this tendency, we concluded that the environmental context may serve as a structural element of an interaction system tailored for commuting in autonomous cars.

(C) Speed-based Behavior Patterns. Our observations showed that the performance of the activity itself seems to be structured by the changes of the car's speed. The mobile phone usage was particularly affected: as soon as the car stopped, the commuter started writing something until the car started again. Our interpretation of the footage shows that almost every change in speed resulted in a shift of or change in activity. We concluded that the rhythm of an interaction, e.g. a game, may need to be aligned with the vehicle's speed for an optimal experience.

(D) Standstill as Game Changer. A total standstill of the car appears to be one of the most undesired events in any driving situation. As seen in Figure 4, some commutes have frequent standing periods. These standing periods are a key to behavior changes. This emphasizes that one challenge for entertainment in autonomous driving could be to design the car's standstill in a more pleasurable way.

Temporal Design Frames

From the comments and narrations of the in-car interviews, we identified three temporal frames that may play a major role in designing applications for commuters in autonomous cars.

1. Moment-based focus. This refers to the current commuting experience mediated by the rhythm of the traffic. Most of the comments and annotations regarding this temporal context were made describing the experience of the traffic, such as presented in the experiential contexts. We assume that applications targeting this scope would have to leverage the traffic and environmental context, in particular (B), (C), and (D), in order to provide a unique car or commuting-based user experience. For example, regarding the heavy stop-and-go traffic of case 1 with frequent but short stops, the design challenges could be described as *how to reframe the stops as part of an interaction system?*

2. Journey-based focus. The daily journey to work presents itself as a dualism of work and home trips with very different preconditions. Interaction systems targeting commuters on this level may benefit from a consideration of this work-home disparity observed in (A). With this in mind, the design challenge should focus on *supporting the transformation process of the commuter*.

3. Routine-based focus. Commuting is often experienced as an everyday life issue that seems to be beyond the commuter's control. Commuting does not seem to be experienced as a negative or positive activity. Interestingly, most comments resulted from a positive evaluation of a negative expectation such as *"usually, they are bumper to bumper here"* or related to a less interrupting traffic situation such as *"this part is taking sometimes hours ... everyone who turns right will cause everybody else to stop"* (case 1). A similar effect could be observed in the overall evaluation of the commuter's trip. All three participants reported that

this particular commuting trip was less congested or stressful than the usual ones. Based on this evaluation, we anticipate that an *increased awareness of the commuting activity might also increase the feeling of control over the commute that results in an increased well-being of the commuter.* Examples could be interactive or gameful commuting diaries and tracking applications.

Limitation and Discussion

Despite the early stage of the research and the limited number of participants, the findings suggest that a contextual inquiry approach in an improvised autonomous car enables an understanding of the design challenges of commuting experience in future autonomous cars.

The preliminary results accentuate that the design of such in-car activities will benefit from an alignment of contexts and design foci, in particular regarding the traffic situation. However, the suggested context and temporal design foci are not particular specific for autonomous driving. They are also characteristic for traditional car commuting. We assume that these non-specific findings result from the major drawback of our approach: substituting an autonomous driving experience with a passenger experience. As mentioned earlier, the first encounters of self-driving cars will likely affect a feeling of control and a loss of competence for the driver. However, after this phase of adaptation, it is very likely that the autonomous driving experience will resemble a passenger experience similar to our study. We believe that our approach will help interaction designers to envision routine scenarios of future autonomous driving. Another phenomenon is the dominance of the mobile phone usage of the participants. We explain this by a lack of entertainment alternatives. As a substitute of driving, we interpreted the use patterns of the mobile phone to indicate how the contextual rhythm of the driving may influence in-car interaction systems.

Conclusion and Future Work

From our preliminary findings, we concluded that future use cases, such as autonomous car commuting, could and should be explored with contextual inquiry methods. While the findings are highly interpretative and require further validation with a bigger sample size, they already enable us as designers to construct a more realistic reading of the context and of the design challenges of autonomous car-based commuting. The results show that autonomous driving and its real-world use cases require a focus on the situation specific contexts to enable a pleasurable driving and entertainment experience.

Assuming that future everyday use-cases of autonomous driving such as commuting will closely resemble a current passenger experience, our approach of studying future commuting experiences seems to be very promising. Instead of adapting a wizard-of-Oz approach, we believe that a more long-term evaluation of passenger-based commuting will provide more relevant and detailed input. In order to do so and eliminate the newness of the situation effect, we plan to test each participant over several days and provide him or her with an enjoyable activity suitable for an autonomous driving situation.

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