Investigating User Needs for Non-Driving-Related Activities During Automated Driving

Bastian Pfleging
LMU Munich
Munich, Germany
bastian.pfleging@ifi.lmu.de

Maurice Rang
LMU Munich
Munich, Germany
maurice.rang@campus.lmu.de

Nora Broy
BMW Group
Munich, Germany
nora.nb.broy@bmw.de

ABSTRACT

In this paper, we investigate which non-driving-related activities drivers want to perform while driving highly or fully automated. Beyond the available advanced driving assistance functions, we expect that highly automated driving will soon be available in production vehicles. While many technological aspects have been investigated, it is not yet clear (a) which activities the drivers want to perform once they do not have to steer or monitor their car any more and (b) which of those will be feasible. In contrast to prior (survey-based) research, we investigate the driver's needs for such activities by employing a combination of a web survey, in-situ observations, and an in-situ survey. Also, we have a look at the specific requirements of the European / German market in contrast to prior research conducted mostly for English-speaking countries.

The findings indicate that besides traditional activities (talking to passengers, listening to music), daydreaming, writing text messages, eating and drinking, browsing the Internet, and calling are most wanted for highly automated driving. This shows the potential for mobile and ubiquitous multimedia applications in the car.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces

Author Keywords

Highly automated driving; non-driving-related activities; non-driving-related tasks; in-vehicle interaction; automotive user interfaces.

INTRODUCTION

Advances in vehicle technology already enable functions to assist the driver in many ways. In the near future, we expect that highly automated driving (HAD) will be available not only for prototypical cars but also for production vehicles. With the advent of automated driving the requirements considerably shift for automotive user interfaces (UIs). As minimizing driver distraction is the key for designing conventional automotive UIs, the driver in a highly or fully automated car might be more like a passenger. This allows drivers to draw their full attention to other tasks than driving. Kun, Boll, and Schmidt elucidate four research challenges for automated cars [9]: driving safety, the car as a place of productivity and play, new mobility possibilities, as well as user privacy and data security. As safety is the most important aspect, prior research mainly focused on the driver's re-engagement in the driving task. In particular, this relates to the situation when the car immediately prompts the driver to take-over the driving task [6, 7, 10].

Another important aspect mentioned by Kun et al. [9] addresses the so-called non-driving-related activities or tasks (NDRAs): While driving highly or fully automated, "drivers" are able to perform a multitude of activities and can fully concentrate on those (e.g., writing text messages, playing a game). As Kun et al. [9] particularly mention the car as a place for productivity and play, we assume that there are various activities people like to perform (e.g., relaxing). With this regard, it is important to understand (1) which activities are most desired by the drivers, (2) which of these activities can be allowed during HAD, and (3) which of them will actually be accepted by the drivers. In addition to that, it is particularly interesting how the driver's workspace (cockpit) may be adapted for a better support of such activities.

In this paper, we investigate the users' expectations and demands for NDRAs during highly automated driving. We see this as a first step towards offering such activities during a highly automated ride. Investigating the drivers' demands for highly and fully automated driving is challenging since it is an chicken-and-egg problem: Most drivers or passengers have not yet had the chance to experience an automated vehicle. Thus, it is difficult for them to fully imagine such a future scenario and judge the potential. They might come up with different activities and ideas once the technology is widely used. However, we believe that by combining different methods, we can extract a first approximation of future in-car activities.

Contribution Statement

This paper presents the findings of three different investigations that we conducted to infer the driver's needs during HAD. They especially focus at current activities as a driver or passenger (e.g., in a car or public transportation) as well as at expected activities during HAD. The employed methods include (1) an online survey, (2) an in-situ survey conducted

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in suburban trains, and (3) in-situ observations from public transportation (subway).

Besides explicitly asking about NDRAs during an automated ride, we also observed and asked which activities people currently do while on the go as a car driver or as a passenger in public transportation. In combination, these observations serve as an indicator for those activities that the drivers of highly automated vehicles will demand. These findings shall serve as an input for future prototypes and evaluations with the aim to investigate the suitability of certain NDRAs during highly automated driving. Additionally, these findings are expected to support the design of user interfaces for automated vehicles by providing an overview of which functions and activities the interface will need to support.

RELATED WORK

Automated driving has already been discussed in various aspects in related work. In this section, we especially have a look at the different types of driving automation and the tasks which the drivers need or want to perform in the car.

Our work especially targets those levels of automated driving where the driver neither has to maneuver nor to monitor the car. Various organizations such as the German Federal Highway Research Institute (BASt), the National Traffic Safety Administration (NHTSA), and SAE classified the different levels of driving automation. Taking the SAE definition SAE J3016 [17], as a basis, we investigate NDRAs especially for SAE level 3 ("conditional automation"), level 4 ("high automation"), and level 5 ("full automation").

During conditional automation / level 3, the automated car fully takes over longitudinal and lateral control of the vehicle. In addition, the monitoring of the vehicle is taken over by the autonomous system, too. This level still requires the human driver as a fallback solution in case automation fails. Instead, level 4 and 5 (SAE) do not force the driver to appropriately take over the driving task with level 5 automation being able to handle all roadway and environmental conditions.

According to the definition of Bubb the traditional driving task can be divided into primary, secondary and tertiary driving tasks [2]. The *primary driving task* comprises all tasks in direct relation to the real drive (longitudinal and lateral control). *Secondary driving tasks* are those activities that depend on and support the primary driving task. *Tertiary driving tasks* have no direct relation to actual driving. Generally, the driver influences with these activities the comfort conditions of the vehicle, such as the air conditioning or entertainment and communication.

Looking at the responsibilities of the driver during a (at least) highly automated ride, none of the traditional primary and secondary tasks need to be performed. Instead, the driver can dedicate attention and time to what we referred to as tertiary tasks so far and which therefore become the major (i.e., "primary") task. To avoid referring to the same activity (e.g., calling by phone) as a tertiary task during manual driving and as a primary task during HAD, we use the term of *non-driving-related activity or task* [4, 14, 16] to describe all tasks that are not related to driving the car. These comprise those tasks that are (potential) tertiary tasks during manual driving and the main activities during HAD.

Investigating Needs for Automated Driving

The drivers' opinions on (highly) automated driving have already been investigated with regard to certain aspects. However, oftentimes surveys mainly looked at trust and acceptance of the technology in general. These aspects have for instance been investigated by carinsurance.com[1], McKinsey [11], or J.D. Power[2], who investigated the willingness to spend on specific features such as automated driving on future vehicles. The carinsurance.com survey investigated with one question what drivers would "do with their newly freed time". Texting and talking was the most frequently stated activity (26 %), followed by "other" (21 %, includes enjoying or observing the road), and reading (21 %). Less frequently, also sleeping (10%), movies (8 %), playing games (7 %), and working (7 %) were mentioned.

Schoettle & Sivak examined the public opinion regarding self-driving-vehicles through an online survey in the U.S., the U.K., and Australia [18]. Beside the expected benefits and concerns, their survey also asked a first question about how the participants would spent their extra time in a self-driving car. The results show that most respondents would "watch the road" (41 %) while the second most frequent answer reflects the skepticism of the participants: "I would not ride in a completely self-driving vehicle" (22 %). Regarding the answers that address activities, the most frequent responses are reading (8 %), texting or talking with friends or family (8 %), and sleeping (7 %). Similar findings from an online survey were presented by Cyganski et al. [3].

These surveys already give a first impression whether and how people want to spent their time in a self-driving vehicle. However, their granularity regarding activities was often rather low as well as the cultural focus was mostly on the United States of America and other English-speaking countries. In contrast, we aim at specifically investigating possible activities in self-driving cars in more detail and illuminate the German and Continental European perspective. Therefore, we did not only conduct an online survey, but did also conduct an in-situ survey in suburban trains and additionally observed the activities of passengers in the subway. Through this approach we claim to provide data with higher ecological validity, which ideally serves a basis for designing automotive user interfaces and activities for self-driving cars. We believe that passenger situations like taking public transportation provide a first insight and the best available estimation of future activities in automated cars. However, given the public situation in trains, we assume that the set of activities in the car will be even broader as it is a private space.

[1] http://web.archive.org/web/20150910142026/http://www.carinsurance.com/Articles/autonomous-cars-ready.aspx, last access: 2016-10-25

[2] http://www.jdpower.com/press-releases/2012-us-automotive-emerging-technologies-study, last access: 2016-10-25

APPROACH

Analyzing the users' needs regarding HAD is different to research on traditional AutoUI topics since most drivers / users have not yet had the chance to drive an automated car. Thus, it is very hard for them to imagine the capabilities, which influence the potential choice of NDRAs during an automated ride in the car. In order to approximate future use despite the users' lack of HAD experience, we employed three different methods to investigate the drivers' needs in regard to NDRAs.

As a first step, we decided to use a *web survey* in order to gather a set of impressions on a larger scale and set the reference frame for future investigations. In this web survey, we collected information about current activities while driving manually or being a passenger (in public transportation). In addition, we asked about expected activities during highly automated driving. By asking about activities performed as a passenger today, we expected to get an impression of potential activities that the participants will perform while being the passenger (i.e., the non-supervising driver) of an automated car.

In order to verify and enrich the information about current passenger activities, we conducted a *contextual observation* in subway trains around Munich where we observed which activities the passengers perform during their subway rides.

Since the contextual observation only provides a spotty impression of passenger activities, we decided to conduct additional *in-situ interviews* in suburban trains where we asked the participants about their typical / current activities on the go, their travel behavior, and their expected behavior change for automated driving. One goal of these interviews was to not only find out about the activities during the time of observation but the typical and most frequently performed activities on the go. In comparison to a web survey, these interviews have the advantage of being conducted in the right context, which has an influence on the provided answers as we show later on in this paper.

WEB SURVEY

In order to get a broad overview of the users' expectations of highly automated driving, we set up a web-based survey.

Method

The survey was publicly available and invitations to participate were distributed via e-mail, Facebook, faculty mailing lists, and learning platforms. Our goal was to gain knowledge about current activities the participants perform (1) during a car ride as a driver, (2) as a passenger on the go (not solely in cars, but also in other means of transportation like buses or trains), and (3) to investigate the drivers' opinion on HAD. Therefore, we asked questions about which activities the participants expect to perform during a highly automated drive.

Procedure

The survey was hosted on a publicly available web server using LimeSurvey[3] to present questions and record the contestants' responses. The whole system was set up in German and, thus,

[3] https://www.limesurvey.org/, last access: 2016-10-25

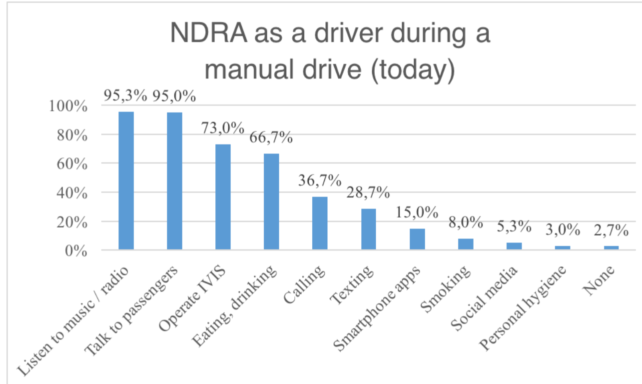

Figure 1. Web survey: Non-driving-related activities performed already today as a driver (multiple responses).

focusing German-speaking participants. At the beginning, an introductory page was shown to inform about the goal of this questionnaire (non-driving-related activities during a car ride). Additionally, the participants were informed that their participation is voluntary and that they can interrupt and resume the questionnaire whenever they like. They were able to fill out the survey without revealing their identity. As a reward, two Amazon vouchers (15 €) were drawn from all participants. On average, the survey was completed in 15 min.

Employing the survey, we wanted to investigate what kind of activities the participants perform during a ride today (as a driver or passenger in a car or other means of transportation) and what kind of activities they expect to perform during a highly automated drive. Therefore, we first presented a set of questions about the participants' current activities during a car ride. Next, we asked about what kind of activities the participants perform during a ride in public transportation. As a next step, we presented the idea of highly automated driving and asked about the participants' willingness to use such form of driving a car. In addition we asked about activities the participants would like to perform during a highly automated drive. Finally, we asked (optional) demographic questions. The questions were designed in a neutral way to neither encourage contestants to exaggerate performed or desired activities nor to be afraid of mentioning these activities.

Participants

In total, 300 participants completed the survey throughout a period of two weeks in December 2015. For the participants' age we asked about belonging to a specific age group (17–20, 21–30, 31–40, 41–65, older than 65 years). The largest group of participants belonged to the age group 21–30 years (60.7 %), followed by 17–20 years (18.7 %), 31–40 years (11 %), 41–65 years, and older than 65 years (1.7 %). 156 participants were female (52.0 %), 134 male (44.7 %); 10 participants did not tell (3.3 %). With regard to their occupation, 27.3 % of the participants were employees, 3.7 % were freelancers, four participants were pensioners (1.3 %), two participants were not employed and five participants did not tell. 65.3 % of all participants stated that they were enrolled as university student. All participants owned a driver license that allows them to drive a car.

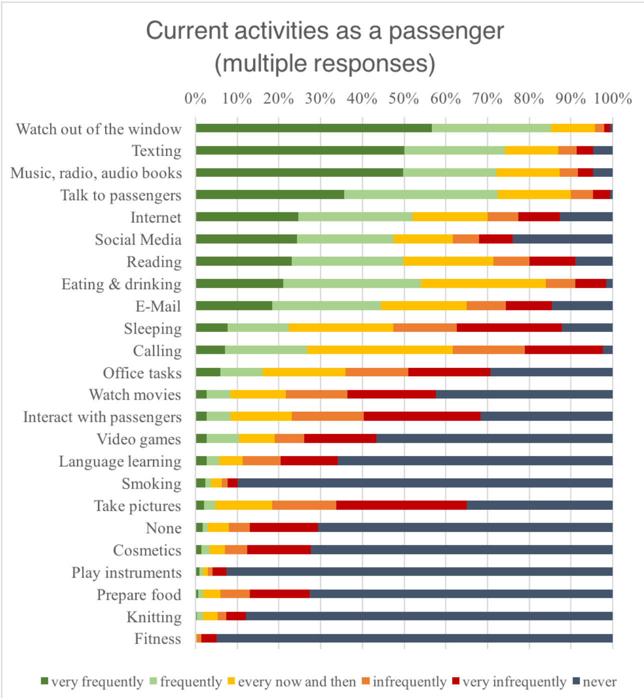

Figure 2. Web survey: Activities as a passenger in cars or public transportation.

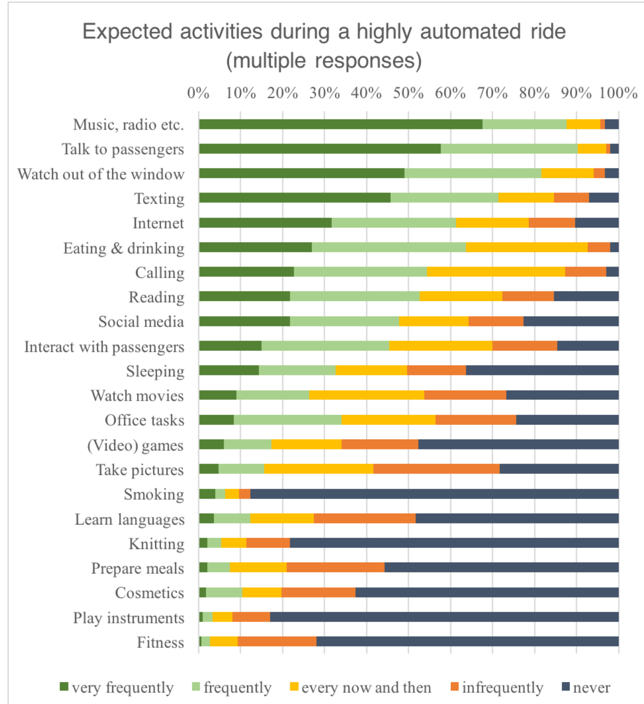

Figure 3. Web survey: Expected activities during a highly automated car ride.

Results

First, the participants were asked which activities they carry out **during a car ride as a driver today**. Here, participants could choose multiple activities. The activity mostly named by the participants was listening to music. 95.3 % of the participants named this activity. Scarcely behind, talking with passengers (95.0 %) was named. Interacting with the in-vehicle infotainment system ranked third (73.0 %). This is followed by eating/drinking (66.7 %), calling (36.7 %) and texting (28.7 %). The distribution of all activities is shown in Figure 1.

Second, we asked the participants about the frequency of certain **activities as a passenger** in a car or public transportation. For this question, the participants also had to rate how frequently they perform each activity. Figure 2 shows the distribution of the provided answers (grouped by expected usage patterns from “very frequently” to “very infrequently”, and “never”). If we add up the percentages of very frequent and frequent activities, watching out of the window is the most frequently performed activity (85 %), followed by texting (74 %), talking to passengers (72.3 %), listening to music / radio / audio books (72 %), drinking and eating (54 %), surfing the Internet (52 %), reading (49.7 %), social media (47.3 %), and e-mail (44.3 %). Additional activities above 10 % were calling (26.7 %), sleeping (22.3 %), office tasks (16 %), and playing video games (10.3 %).

The third category of the survey dealt with the topic **highly automated driving**. As a first question, we asked whether they could imagine *buying a highly automated vehicle*. 44 % of the participants stated that they could imaging buying a car with high automation if it is not too expensive. Another 21 % would do so if the vehicle provides more opportunities and extended comfort. 10 % would even buy such a car if it costs more. The remaining quarter of the participants could not imagine to buy a highly automated vehicle.

The next question should determine which activities the participants would expect to perform *during highly automated driving*. Figure 3 shows the distribution of the different activities that we proposed. Adding up again the percentages of very frequent and frequent use, talking to passengers (90.3 %), listening to music/radio etc. (87.7 %), and watching out of the window (81.7 %) were the most frequently expected activities. Furthermore, participants would write (any type of) text messages (71.3 %), eat and drink (63.7 %), surf on the Internet (61.3 %), make phone calls (54.3 %), read (52.7 %), dedicate time to social media (47.7 %) or interact with passengers (e.g., play games, select the next destination, 45.3 %), perform office tasks (34 %), sleep (32.7 %), watch movies (26.3 %), play (video) games (17.3 %), take pictures (15.7 %), learn languages (12.3 %), or perform activities related to personal hygiene (10.3 %).

We also allowed to name *other activities* that were not listed in the questionnaire. This opportunity was taken by a total of 65 participants. Here, the most frequently mentioned activities were: learning, working, control the vehicle, and (video) telephony like Skype. The last and final question on this topic was concerned with the interaction during HAD. Specifically, in this question the participants should answer which devices they prefer to interact with during HAD. The device which would be most used by the participants is the smartphone (75.5 %). Second, the in-vehicle information system (IVIS)

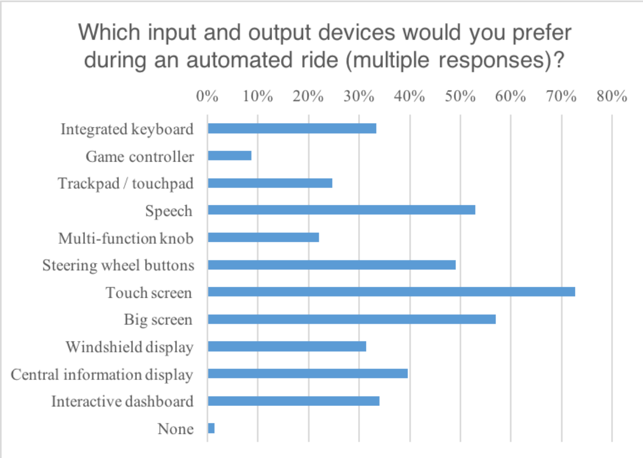

Figure 4. Web survey: Preferred input and output technologies for automated vehicles.

followed with 61.3 %. Tablets ranked third (53 %) followed by a laptop computer (43.3 %). 15 participants (5 %) did not want to interact with any devices and only 10 persons wanted to interact with a smartwatch (3.3 %) during HAD. When asked about specific input and output devices, we saw a diverse image as shown in Figure 4. Touch screens (72.7 %) and large screens (57 %) in general were preferred among the output devices. For input, one interesting finding is that 53 % of the partcipants could imagine using speech.

Discussion

The results found in our survey are in line with prior research and provide a good overview of future activities. Interestingly, many desired activities are already performed today, such as talking on the phone, or reading and writing text messages. Looking at the activities performed as a passenger today, we see that these might be a good indicator for future HAD activities. However, we see that some of these activities would be performed much more frequently during a highly automated ride. Compared to riding as a passenger today, it is interesting to see that making phone or performing office tasks calls would almost double for HAD. Also, we see that many of the most frequently mentioned activities are related to tasks and Apps people use in everyday life on their smartphones.

Already the web survey reveals that also relaxing or idling activities (e.g., watch out of the window) are activities that passengers want to carry out during automated driving. Similar findings have been reported by Schoettle and Sivak [18].

CONTEXTUAL OBSERVATION: SUBWAY

Estimating future user behavior for HAD is challenging since only very few people had the chance to experience an automated driving situation so far. Due to this lack of experience, it is difficult for contestants to imagine the situation and furthermore estimate which activities they would perform in such a situation. On the other hand, we assume future drivers in automated cars will perform at least a subset of those activities that people already perform on the go today as a driver or as a passenger. In order to complete the image on passenger activities, we therefore decided to perform a contextual observation in public transportation. The goal of this observation was to get a first unbiased estimate of which activities the passengers carry out during the journey.

Method

We performed a contextual observation of passenger activities in public transportation with the goal to identify activities passengers carry out during their journey. The observation was conducted in subway trains ("U-Bahn") in and around Munich in November 2015. We decided to focus especially on subway trains since they are typically used for short to medium distances within cities which is comparable to a majority of car rides as well.

Procedure

We selected different weekdays (workdays and weekends) and also different times of day for our observations. The idea was to examine which activities when and with which frequency are carried out by the passengers. As a preparation for our contextual observation, we collected a list of potential activities from brainstormings and the web survey. We used this list as a basis for our observations and extended it with all additional activities that we identified during the experiment.

For the observation itself, the experimenter entered the first or last car of a subway and observed and counted the current activity of each passenger in this car. For each passenger only one activity was counted. Once all activities had been counted, he moved to the next car and so on until all cars had been visited. This procedure was repeated for different trains and routes as well as different weekdays and times.

In order to maintain the passengers' privacy, we summarized some of the observed activities. For instance, we did not distinguish the use of certain applications on mobile phones which would only be possible by observing the actual screen contents or asking the passengers.

Participants

Since we did an anonymous observation of the passengers in the subway trains, we cannot provide an exact description of the participants / passengers. In general, we tried to observe the behavior of passengers of all age groups, from school children to (great-) grandparents, i.e., passengers aged between 10 and 80 years. The observed audience varied across the different times of the day and weekdays. One of the strongest represented target groups were passengers aged between 25 and 50 years.

Results

Since we only performed very short-term observations per passenger, we can only report on one activity per participant and cannot distinguish between different activities and frequencies per passenger as we did in the web survey where multiple responses could be provided. This also results in a high number of items that did not appear in the web survey (e.g., performing no activity at all / day dreaming, 18.5 %) as shown in Figure 5. We identified reading newspapers, magazines, or books as one of the most commonly performed activity in the subway (16.1 %). This was followed by talking to passengers (14.3 %),

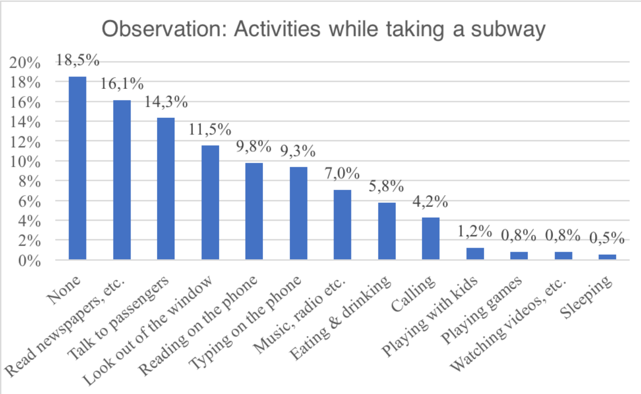

Figure 5. Contextual observations: Passenger activities during subway rides.

looking out of the window (11.5 %) even though there was not much to see. Due to the limited behavior that we could observe unobtrusively, we classified activities on the phone as either reading (9.8 %) or typing (9.3 %). If we combine these two activities as using the mobile phone, this activity was the most frequently performed activity (19.3 %). Slightly less frequently, the subway passengers listened to audible content (7 %), ate or drunk something (5.8 %), or called someone on the phone (4.2 %). Figure 5 presents all activities that we observed during our experiment.

Discussion

By observing passengers while using public transportation, we were able to understand which activities people perform on the go and how they spend their time while getting to their destination (cf., Figure 5). The most frequent activity was actually none. That means people use this time to come down and relax. We assume that relaxing is a major need during automated driving and should allow the driver to simply change the interior to a comfortable environment, e.g., by adjusting the seat to a relaxing position.

In general, we assume that the observed activities are only a subset since some activities might not be carried out due to privacy reasons, social norms, or other restrictions. Examples could be the avoidance of speech input in public transportation as a mean for writing text messages or preparing slides for the next business meeting (privacy issues).

Also, the car is often a private space since people in Europe and North America drive most of the time alone in their car. This influences certain activities, for instance regarding communication: If nobody else is in the car, talking to passengers does not make sense. Instead, it is more likely that the driver calls someone outside of the car in such a situation or talks to a speech assistant as such systems are currently gaining acceptance [12]. The differences regarding space and fellow travelers could also cause interaction with activities to be different in comparison to public transportation, e.g. using speech interfaces instead of keyboards and touch surfaces.

IN-SITU INTERVIEWS IN SUBURBAN TRAINS

In order to also get situational feedback about activities on the go as well as on highly automated driving, we decided to conduct additional semi-structured interviews in suburban trains. We did so to investigate details about passengers' performing activities while being on the go (during a ride with a suburban train) since this may be a situation similar to riding an automated car. In addition, we wanted to see, how the current context affects the estimation of which activities participants would like to perform during a highly automated drive.

Method

We conducted these semi-structured in-situ interviews in suburban trains ("S-Bahn") in and around Munich. One major goal was to find out which activities the interviewees carry out during a journey in public transportation. In addition to that, the passengers were asked about which changes they would expect with highly automated driving. In contrast to the contextual observation, we conducted these interviews in suburban trains ("S-Bahn") in and around Munich. Typically, passengers travel slightly longer distances with these trains. Initially, we also wanted to conduct the interviews in the subway. However, due to limited permissions of the operating company, we were only allowed to conduct interviews in suburban trains.

Procedure

At the beginning, the participants were informed about the goal of this questionnaire (non-driving related activities during a ride with public transportation). Additionally, the participants were informed that their participation is voluntary and that they can interrupt and resume the interview whenever they like. They were able to fill out the survey without revealing their identity. The participants did not receive any financial compensation. On average the interview took about 10 min. In order to understand passenger activities, we asked questions about their travel behavior, activities as a passenger, and expected changes with highly automated driving being available. Since suburban train rides might not take too long, we decided to choose only a subset of questions in comparison to the web survey in order to make sure that participants finish the interview before exiting the train. Also, we addressed the issue of taking this specific way of transportation during the interview.

Participants

The acquisition of the participants happened by approaching passengers in the train. We made sure that all participants owned a valid driver's license to maneuver a car. The participants owned their license between three and 57 years ($M = 24$ years). In total, 43 participants took part in our interviews. For asking about the participants' ages we chose the same age groups as in our web survey. This time, the group of the participants aged between 41 and 65 years was largest (35 %). The distribution of the other age groups was as follows: the group 17–20 years was represented with 12 % and the participants aged 21–30 years formed 18 % of the participants. 19 % of the participants were aged between 31 and 40 years, and 16 % were aged 65 or older. Among the interviewees, 33 % of them were employed, 16 % of them were freelancers, others were students (16 %), pensioners (16 %), currently not employed (12 %), or pupils (7 %).

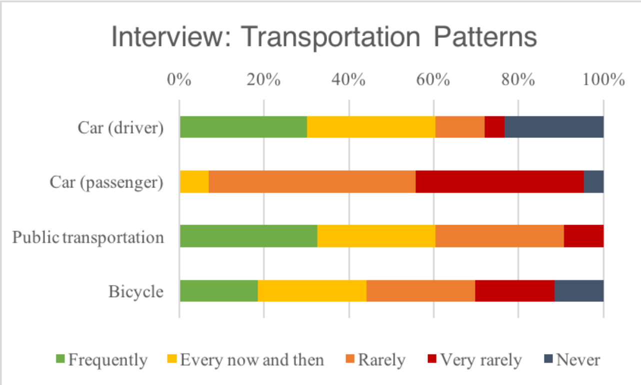

Figure 6. Train interviews: Transportation choice of the participants.

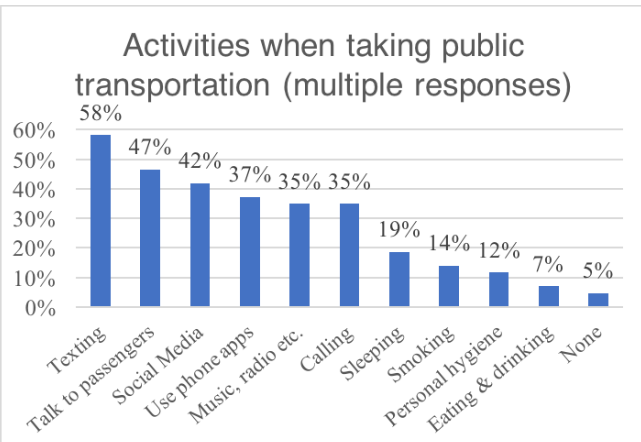

Figure 7. Interviews in suburban trains: Activities the participants perform in public transportation.

Results

Primarily this survey was used to find out which activities the passengers perform during a ride with a suburban train. Besides the basic demographic questions, we asked the participants about their current patterns for choosing means of transportation. Figure 6 shows the detailed response of all participants. When summarizing the two categories "frequently" and "every now and then", public transport is the most frequently chosen means of transportation (61 %), followed by driving a car (60 %), and riding a bicycle (45 %). In contrast, participants only rarely are car passengers. When asked about reasons why some of the participants preferred public transport over driving a car, the most common reason was that public transport enabled a quicker or better connection to the desired destinations, followed by cost and time as other reasons.

When asked about activities that the participants perform in public transportation (multiple responses possible), the majority of passengers dealt with text messaging (58 %) or talked to (other) passengers (47 %). Really interesting for research in the area of HAD too, 42 % of the participants used social media features or other phone apps (37 %). Calling on the phone is an activity that was only performed by 35 % of the passengers. The same value holds for listening to audible content such as music, radio, or audio books. Less commonly, 19 % responded to also take a nap when taking public transportation. The other activities as shown in Figure 7 appear with a relatively low occurrence.

With regard to HAD, we used open questions to gather the interviewees' opinions. 51.1 % of the participants expect that the availability of highly automated driving functions will change their mobility patterns. When asked about concrete changes, the participants stated that they expect to have more time for personal activities such as phone calls or watching video content. In addition to that, some participants stated that they expect that automated driving will take out some of the stress that they currently experience on the go, which will make a ride more enjoyable and relaxed. Especially, some of the elderly interviewees stated that they expect to be able to take longer rides with a highly automated car since they do not have to perform strenuous driving activities any more.

Discussion

The results of our in-situ interviews reveal some interesting aspects. The distribution of activities is slightly different in comparison to the results of our web survey where we also asked about passenger activities. For instance, texting was only stated by 58 % of the participants in the train in comparison to 74 % of the participants from the web survey. We observed lower percentages also for most of the other categories such as talking to passengers (72.3 % from the web survey vs. 47 %), drinking and eating (web survey: 54 % vs. 7 %), listening to audio content (web survey: 72 % vs. 35 %), and using mobile phone apps (web survey: 52 % for Internet, 44.3 % for e-mail in comparison to the overall number of 37 % for mobile apps as gathered during the interviews). One potential reason for this observation is that some activities such as calling, using speech input, or accessing personal information and documents are performed less frequently due to privacy concerns in public environments. Since the interview was performed in-situ, we expect that the results are closer to the actual user behavior.

If we compare the results of the in-situ interviews with our observations, some interesting differences can be found. Most important, performing no specific activity (e.g., relaxing), was the most observed activity in our observational study but was the least frequently stated activity in our in-situ interviews. We assume that most participants did just not state that "doing nothing" is also an activity they frequently perform. As shown in prior work [13] there may be difference between reported (past) behavior and actual behavior. As multiple responses were allowed when reporting activities during the interview, percentages are higher compared to the observation where only the current activity of each passenger was denoted.

GENERAL DISCUSSION

The three different methods that we employed provide a diverse impression of (non-driving related) activities that people currently perform on the go or that they expect to conduct during a highly automated drive in the future. We identified a broad set of activities beyond those that are already commonly performed in the car or elsewhere on the go. The automated car is more than a place for play and productivity [9] as we identified a high demand for example for relaxing, daydreaming, sleeping, and looking out of the window.

Limitations

Since most users have not yet experienced an automated ride, it is difficult to estimate their future user behavior. One limitation of our data is that the observations from public transportation cannot be fully transferred to automated cars since the latter offer a more private space. This has two implications: (1) passengers of automated cars might perform privacy-sensitive activities which are not possible or accepted in public spaces. (2) People might perform activities in a different way when comparing public transportation and automated cars. For instance, phone or video calls may be preferred over text messages in the car as well as speech interaction may replace typing to enter text when driving in an automated car. However, we assume that the provided sets of activities are a good starting point for future research. As our observations and surveys took place in Germany, we extend the view on such activities especially from a German perspective.

In addition, we need to keep in mind that two of the three methods (web survey and interviews) are based on reports by the participants. With this regard, we have to acknowledge that (past or future) reported behavior and actual behavior do not always coincide [13], which makes it difficult to interpret this data alone. Thus, it could be difficult to infer usage frequencies from these investigations. However, our focus was to find out which activities are generally desired without a need to identify a specific ranking.

Identified Activities

Doing nothing

Interestingly, doing nothing specific was the most observed activity in our subway observation. This highlights the need for a relaxing environment (seat position etc.) for automated cars. However, for a re-engagement in the driving task these changes should be reversible immediately to allow the driver an easy handling of the steering wheel and the pedals. Future research has to clarify how fast such a reorientation can happen in case of a take-over.

Entertainment, Physical Needs, Watching out of the Window

Known activities comprise listening to audible content (music, radio, audio books etc.), talking to passengers, eating and drinking, or just looking out of the window - either to observe the road or enjoy and observe the landscape. We identified all of these activities as tasks for highly automated driving. Since observing and watching the environment was a very common activity, this could be exploited by (3D) Head-Up [1] or windshield displays [8] in future vehicles. Such displays could for example enrich the driver's / passenger's view with additional information to entertain, educate, and inform the driver (e.g., about the automation function by showing the upcoming driving maneuvers of the self-driving car) while keeping the eyes on the road.

Communication, Productivity, Use of Mobile Devices

Communication with the outside world is a very important aspect and includes activities such as texting, calling, and social media. We see that the rise of smartphones increased this need of being always online and connected to family, friends, and colleagues [15] and believe that this will remain a very important aspect in the future. In addition to that, we see that people as passengers currently perform a variety of activities using their mobile devices (smartphones and tablets) and expect such activities also for a highly automated ride. This includes web surfing, watching videos, playing games, e-mail features, and other office-related tasks. One interesting aspect for future research is how such activities can be supported by the in-vehicle interface. This includes an investigation of input methods where the automated car may provide new opportunities for alternative input methods, including hardware keyboards, digital keyboards, or enhanced speech input.

Exploiting devices such as smartphones enables the user to perform a multitude of tasks in mobile situations. We assume that future vehicles need to provide a similar set of activities and applications to the driver and future passenger. With this regard, we believe that it is important to provide such features through the systems that are integrated into the car since they are adapted to the specific needs of the (manual and automated) driving situations. However, this means that vehicle systems also need to be as modern as mobile devices that are available to satisfy the users' needs. Nomadic devices brought into the car (smartphones, tablets, or even notebooks) might be inappropriate as long as they do not know about the specific demands of the current driving context and, thus, cannot support the driver appropriately. Examples for such situations are (critical or uncritical) take over situations. Here, one important aspect is the judgment of when and how to inform the driver (e.g., to take the next exit on a highway).

CONCLUSION AND FUTURE WORK

In this paper, we present the results of an combined investigation on non-driving-related activities for highly automated driving situations. By employing different methods (web survey, contextual observation, and in-situ interviews) we were able to provide a diverse image on activities that people currently do on the go (as drivers OR passengers) and which activities they want or expect to perform in an automated car. Summarizing, we expect that highly automated cars need to provide a broad range of applications to support these activities. This includes for instance means for communication, windshield applications, productivity, and entertainment.

Providing desired activities is only a first step towards applications in the automated car. As one of the next steps, it is important to investigate which of the activities will be compatible with the requirements of an automated car. This includes various (technical) aspects such as tasks being easily interruptible (for take-over situations) and resumable. For an ideal user experience, it is desirable that activities can be continued even when driving at a lower level of automation. Therefore, a reduction of task complexity may be beneficial. Another aspect is related to the drivers themselves. Depending on the implementation of an application, self-driving carsickness [5] could negatively affect the driving experience. Here, the design of applications–including the question of where to place input and output devices–may play a very important role. Finally, it will be interesting to investigate how the vehicle interior could be modified to enhance the driving experience and to better support certain NDRAs.

For the situation of highly automated driving and non-driving-related activities, we see many questions which have to be investigated. With the results of our experiments we hope to provide a basis for the design of future non-driving-related activities in highly automated cars. These activities show the potential of the car as a novel space for the consumption of mobile and ubiquitous multimedia applications.

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