Co-Navigator: An Advanced Navigation System for Front-Seat Passengers

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ABSTRACT
In-car navigation systems typically have the purpose to support the driver in a navigation task. While the field of automotive HCI research abounds in driver-focused navigation design relatively little attention has been directed to the front-seat passengers as a support to the driver for e.g., navigation. Based on our ethnographic research, we have designed and prototyped a system called *Co-Navigator*. It was devised to be operated by the front-seat passenger, in order to support the driver in navigation and driving related tasks. The Co-Navigator is an interactive, tablet based navigation app that provides different kinds of information such as landmarks and upcoming hazard warnings (e.g., construction sites or potholes). In this paper, we describe the prototype, its elements, and an explorative in-situ evaluation. Results show that the Co-Navigator is a valuable in-car navigation device for the front-seat passenger. Especially the map overview and hazard warnings were appreciated.

Author Keywords
Collaboration; front-seat passenger; GPS navigation systems; in-situ study.

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

INTRODUCTION
The main purpose of in-car satellite navigation systems is to support the driver in a navigation task. They are designed to be operated by the driver before or during a ride. Thus, one major design goal for GPS systems is not to distract the driver from the driving task. When (front-seat) passengers are sitting in the car such GPS systems may be operated by them as previous research has shown [11]. But none of today's systems are designed to take advantage of the free resources of passengers during a trip. We see potential to design navigation systems specifically for passengers in the car due to the fact that passengers do not have to drive the car and thus have more cognitive resources. We are aware of the fact, that drivers are often alone in a car without any passengers. Nevertheless, in cases where (front-seat) passengers are present, navigating often becomes a collaborative endeavor [11].

Relevant information (e.g., getting more details about the current route or upcoming hazard warnings) may be provided by the front-seat passenger acting as an assisting navigator [4]. Additionally, drivers may need assistance in finding their way along a route in an unfamiliar area or in a case of misguiding. By sharing information about the output of the navigation system, driver-passenger pairs are embedded in a social context, in which collaboration occurs.

Following our ethnographic result [11], we argue that collaborative navigation can help drivers to focus on the main task of driving. On that account, we created a system we label *Co-Navigator*, running on a tablet, which was target as a GPS navigation system for the front-seat passenger. Compared to conventional navigation systems, the Co-Navigator provides more details about the route that could be communicated (via the front-seat passenger) to the driver. This is achieved by providing diverse landmarks that refer to specific locations and various demanding situations (e.g., a construction site, a pothole, or a narrow road), aiming to support the driver in navigation and driving related tasks. In order to evaluate the feasibility of the prototype, we conducted an explorative in-situ study.

The contribution of this paper for the automotive UI community is twofold. First, we provide a novel interface of a navigation system, designed to be operated by passengers. Second, we want to use our results to inspire future in-car navigation designs for passengers aiming to support drivers. In this paper, we describe the prototype, its elements and the evaluation of the Co-Navigator. In the results section, we show relevant information and features that support the front-seat passenger's assistance as well as trigger collaboration between the driver-passenger pairs. Finally, we describe how the Co-Navigator was experienced and evaluated by the participants.

BACKGROUND AND RELATED WORK
The following chapter briefly presents problems and potentials concerning the use of current in-vehicle

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navigation assistance systems, as well as, social and collaborative aspects of in-car navigation, which sets the background for our prototype.

Problems and Potentials of Current Navigation Systems

Current in-vehicle navigation systems are occasionally counterintuitive and not particularly helpful to users. For instance, Hipp et al. [5] have found that commercial GPS units frequently fail to provide directions that correspond with drivers' intentions. Kun [6] investigated how navigation systems distract drivers and lead to additional driving errors. Leshed et al. [8] report that navigation systems contribute to a feeling of being lost. Another distracting effect of current navigation systems is that the driver has to move attention away from the road to interpret navigation information.

According to Forlizzi et al. [4], visual information, which is often crowded on the navigation display, makes it more complicated to read information at a glance. Additionally, the timing of visual and auditory cues can be problematic, resulting in instructions that are given too late before the next maneuver. The drawback of current in-vehicle navigation systems is that they have not yet reached their full potential. In an ethnographic study [11] we found out that these systems do not necessarily need to be used by drivers alone. We argue that a move from an individually-focused design paradigm to one based on collaborative human interaction holds a great potential in improving mediated human-human interaction in the car.

Social and Collaborative Navigation

Regarding collaboration within vehicles, a notable body of research in HMI exists on driver and front-seat passenger engagement with navigation devices (e.g., [1,3,4,7,8,11]). For instance, Leshed et al. [8] aimed at raising awareness of how the proliferation of in-vehicle GPS technology alters users experiences of their environment. Forlizzi et al. [4] looked at how navigational devices are used in practice for collaboration between adult drivers and front-seat passengers. They found that their collaborative strategies often rely on shared knowledge and experience between speakers and listeners. Brown and Laurier [1] investigated how a GPS is used, in order to inform design that considers users' path finding practices as an integral part of navigation systems. They documented five types of trouble where GPS systems caused issues and confusion for drivers.

Similarly, in [11] we describe that social and collaborative practices of assistance are provided by front-seat passengers. Our ethnographic data shows that current in-vehicle navigation systems are not always sufficient especially at night, in an unfamiliar area, or under bad weather conditions (e.g., snow or poor visibility due to fog). We observed one case where the driver used a portable navigation unit, whereas the front-seat passenger simultaneously aided him in using a smartphone with an overview map. Thus, the driver-passenger pairs made use of additional equipment (i.e., a mobile phone) to achieve their common goal, which was not supported by the custom navigation system. We experienced collaborative navigation as a social task between drivers and passengers to reach a specific destination, using a physical or mental representation of the area [12], rather than an isolated task of the driver (e.g., reading a map aiming to reach a destination).

Based on the literature review and the evaluation of existing in-vehicle navigation systems, we state that navigating while driving works best when done collaboratively — when the driver is assisted by a navigator providing information in a timely fashion, checking for understanding, and offering clarification.

CONCEPTUAL DESIGN OF THE CO-NAVIGATOR

The design idea of the Co-Navigator was motivated by our previous work [13], in which we suggest that front-seat passengers could use display solutions that include more information compared to conventional navigation system to improve collaboration (i.e., a collaborative navigation task).

One aspect was, whether we want to add an additional system for the front-seat passenger or should replace the traditional turn-by-turn navigation system. We decided to add an additional system, since in this case the driver is able to navigate the route without passenger assistance, and the front-seat passenger may support the driver only in demanding situations. Thus, it was important for us that our prototype should complement the ordinary navigation system of the driver as a second system. This means, that the Co-Navigator should be more elaborated than the driver`s system, but also provide the same common features (e.g., turn-by-turn instructions) of custom navigation systems.

In order to provide more details about the route, we decided to implement different kinds of information in the Co-Navigator. First, we wanted to provide the front-seat passenger with an overview of the trip, similarly to a front-seat passenger having a map and knowing approximately the position of the car. Second, we wanted to have the same turn-by-turn instructions as visualized to the driver, including the possibility of a foresight (i.e. show turn-by-turn instruction which would be given next). Third, we wanted to provide a detailed map in which the front-seat passenger could zoom in and out. Fourth, this map should offer the possibility to visualize various landmarks (e.g., monuments, buildings, or other structures). We chose them because they are key elements in navigation, easily recognizable, and will make driving safer [9]. Fifth, we desired to include specific landmarks referring to *demand situations*, such as unmarked pedestrian crossings, construction areas, or hidden potholes. We define demand situations as circumstances that can cause accidents, higher workload for the driver, or generally the need of more attention of the driver. These demand situations should be classified into different categories.

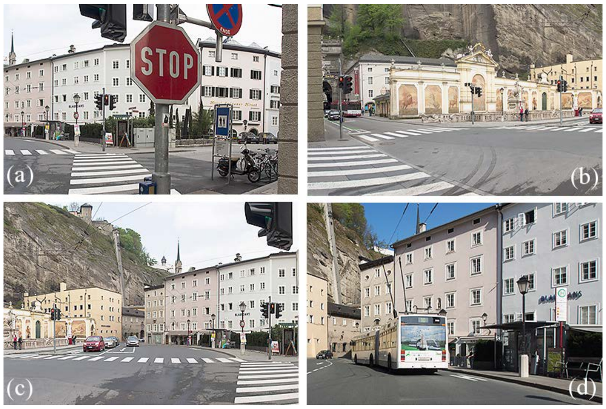

Figure 1. Example of a red demand situation as seen from the car into different directions: (a) view to the right hand side, (b) view to the left hand side, (c) front view and (d) detail from front view (zoomed in).

For the Co-Navigator we suggest to have three types of demand situations: red, orange, and blue. We used this color scheme according to a traffic light system. Low demand situations are classified in blue, because they are still demand situations that need in some cases special attention or assistance. Green would suggest that maybe no action is needed.

A red (high) demand situation, for instance, is a specific route section with multiple junctions together with crosswalks. An orange (medium) demand situation is characterized, for instance, through an unmarked crosswalk near by a parking space. A blue (low) demand situation, for instance, is a simple pothole or a construction site. In order to provide the information on demand situations we chose a specific route in the city of Salzburg with a high number of demand situations, starting at our research institute. We drove this route with our car and videotaped this trip.

As a second step, two researchers independently categorized these demand situations from the video-recorded trip into three levels of demand, based on the degree of workload and attention, color coded as described in the last section (high = red, medium = orange, low = blue). Then, the researchers compared the results. Demand situations that were categorized by both researchers in the same level were used for our initial design sketches. Demand situations that were categorized differently by both researchers were eliminated. This resulted in a route including 54 demand situations (9 red, 12 orange, and 33 blue) that we believe trigger collaborative interaction and, especially, assistance from the front-seat passenger. For example Figure 1 shows pictures for a red demand situation: a demanding crossway. Other vehicles and pedestrians could come from various directions, a bus stop is nearby, etc. The taken pictures were then used to be included in the Co-Navigator prototype.

THE CO-NAVIGATOR PROTOTYPE

In the following section, we describe the key elements of our prototype that was then implemented as an Android App on a 10.1 inches tablet. The screen of the Co-Navigator's user interface is divided into four parts shown in Figure 2: (1) map overview, (2) turn by turn instructions, (3) satellite image including pictures of demand situations and POIs as an overlay, as well as (4) hazard warnings for the entire trip. Each part provides specific information that in combination gives a detailed overview of the driving situation.

The first part is illustrated in detail in Figure 3. It shows a map-based overview of the entire route from the starting point to the destination and was implemented using Google Maps. The current position, as well as, the driving direction, is displayed at all times, using a red arrow in combination with a light blue circle to gather attention at short glances. This enables the front-seat passenger to quickly locate the car's current position with regard to the whole trip. Current GPS systems lack to show this information during driving, only providing e.g., the remaining estimated time to destination.

The second part that is located below this map provides turn-by-turn instructions and informs about the next driving actions as can be seen in Figure 2. In the prototype, the number of turn-by instructions is limited to three to provide an overview of the next actions but also limit the information density. Apart from short instructions symbols are used to indicate the turn direction. The information representation was chosen similar to web-based route planning systems such as Google maps since we assumed that most front-seat passengers are familiar with this kind of navigation information.

The third part of the application shows the current driving situation from a birds-eye view, as shown in Figure 2. This part, located on the right side of the screen, claims the biggest part of the screen and allows different kinds of interactions. The front-seat passenger can choose e.g., between different display options: normal (Google maps based image), satellite, and hybrid (satellite image with overlapped map image) using buttons to choose on of these modalities on the top right side of this area.

Figure 2. The Co-Navigator prototype: (1) map overview, (2) turn-by-turn instructions, (3) satellite image and (4) upcoming hazard warnings.

Figure 3. Part 1 of the Co-Navigator: map overview of the trip.

In Figure 4, the hybrid view of part 3 is chosen. The defined route is marked with a red line in all views. This part of the screen allows similar kind of manipulation as in current web based route planning systems (zooming, swiping, etc.). As a result, the front-seat passenger can explore the surroundings in a flexible way during driving. In order to center on the current driving position again, a special button can be used that is located on the left of the view-selection-buttons, which changes the appearance of the birds-eye view.

Furthermore, landmarks - in our case specific demand situations - are indicated on the screen by colored flags that correspond to the color scheme of the demand classification (i.e., red, orange, and blue). By clicking on a specific marker, an additional frame pops up that shows the demand situation from various perspectives using a cover flow visualization style. An example is shown in the screen overview of the Co-Navigator in Figure 2. The various views help the front-seat passenger to get an overview of the particular demand situation that is normally not supported by custom navigation systems.

Figure 4. Part 3 of the Co-Navigator: current driving situation from a birds-eye view.

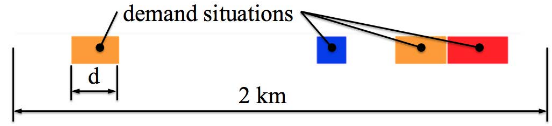

Figure 5. Part 4 of the Co-Navigator: Exemplary bar plot of upcoming demand situations, showing different lengths of various sections.

The fourth part that is located on the top of the screen shows upcoming potential demand situations, such as unmarked crosswalks or potholes. Therefore, a bar plot is used that takes into account a defined color scheme, described in the previous section. An exemplary bar plot is shown in Figure 5. The bar plot shows demand situations up to a distance of two kilometers. In the plot, four demand situations are shown. Their position (the trip starts at the right position) as well as their duration (i.e. length of the bars) are visualized. For example, the duration of the first upcoming demand situation is marked with d in Figure 5. The color scheme together with this graphical representation should support front-seat passengers call appropriate attention on the upcoming demand situations in time.

With this interface design in mind a prototype of the co-Navigator was developed in Android. Map visualizations were taken in real time form Google Maps. Pictures were taken from the initial trip. Interaction with the system was possible. In more detail, the Gson Lib library was used to send and receive serialized objects that control the display information of our prototype. This was mainly used for the Co-Nav Wizard, which could alter the state of the device if e.g., a waypoint was missed or the system did not recognize that a waypoint was passed.

THE EXPLORATIVE IN-SITU STUDY

In order to evaluate the feasibility of our prototype we conducted an explorative in-situ study. We focused on two overall research questions:

1. Which information/features of the Co-Navigator support the front-seat passenger in navigation and driving task as well as trigger collaboration between driver-passenger pairs? (RQ1)
2. How was the prototype experienced and evaluated by the participants? (RQ2)

Note that this evaluation was conducted in an early design stage. Thus, we did not intend to study the usability or driver distraction but rather the ability of the Co-Navigator to provide relevant information to the front-seat passenger in order to support the driver while navigating from point A to point B and to trigger a shared experience between the couples.

Study Set Up

Participants

A total of n=20 (10 couples) were recruited via mailing list and promotions on the website of the research institute.

They were aged between 18 and 39 years. Participants consisted of 6 male and 4 female drivers, as well as 4 male and 6 female front-seat passengers. We chose couples since, according to Forlizzi et al. [4], they are experienced in navigating together and show more efficient strategies for exchanging information during the navigation task than unacquainted individuals.

All participants had experience in using a navigation system while driving, either with dashboard systems or portable in-car navigation systems. All couples were familiar with navigating using Google maps and drove together regularly. Usually, front-seat passengers did the route planning in unfamiliar areas in 3 out of the 10 couples, whereas the rest planned the route together. Only one couple regularly drove our pre-defined route. Half of the front-seat passengers typically assist drivers in demand situations, such as construction areas, unmarked crosswalks, intersections with poor visibility, passing pedestrians, or bad weather conditions.

Procedure

As stated before participants had to drive on a pre-defined route. Travel time, on average, was approximately 33 minutes. Initially, each couple was introduced to the study in their car and answered some general questions with a questionnaire about their driving history and social aspects (e.g., how often they are driving together, who normally navigates through unfamiliar areas, etc.). Then we explained the functions of the Co-Navigator. Afterwards, the couples could decide who the driver would be. The Co-Navigator could be used by the front-seat passenger to assist the driver. Then, we gave the participants the task: "*Please press the start button on the navigation device on the windshield, as well as on the prototype. We have pre-defined a route. Once you have reached your final destination, both navigation systems will show: "You have reached your destination*." Additionally, one researcher was quietly sitting in the backseat, observing the driver-passenger pair and taking notes during the trip. For safety reasons, we avoided asking questions during the drive. When the destination was reached, we interviewed the participants. Questions were either targeted at the couple, to the driver only or to the front-seat passenger only.

Questions concerning the couple:

- What did you like/dislike about the Co-Navigator?
- What would you improve and what was confusing about the prototype?
- What information of the Co-Navigator was helpful to find your destination?

Questions concerning the driver:

- To what extent does the support of the passenger, evoked by the prototype, affect your driving (e.g., more confused, stressed, make it more difficult or easier)?
- How did you experience the support with the Co-Navigator through the front-seat passenger?

Question concerning the front-seat passenger:

How easy/difficult was it to share the presented information of the Co-Navigator with your partner?

Material and Equipment

We additionally installed a custom navigation system into the car (Garmin nüvi 760), which was mounted on the windshield and helped the driver to find the destination. We used the two navigation systems (i.e., the Co-Navigator and the Garmin device) for two reasons. First, as shown in our previous work, drivers and passengers interact with two navigation systems simultaneously to find the destination in an unfamiliar area [11]. Second, in order not to distract the driver by using a second system, we gave the driver the same turn-by-turn instructions on the custom navigation system as the front-seat passenger. Two cameras were fitted into the cars, one covering the area in front of the car to capture contextual factors and a second one recording (video and audio) the driver passenger interaction.

ANALYSIS

Our analysis relies on video-recordings, observations of the interactions with the prototype, as well as post-trip reviews from the participants after the trip. In total, we collected a substantial body of video material, lasting over 6hr, 29min. Journey times ranged from 25 to 45min; the average trip duration was 33min, 41sec. Two researchers investigated the 10 naturalistic recorded trips by editing the videos and audio files (i.e., the post-trip reviews by the couples). After sorting out recorded data, we had 18 video sequences with assistance from the front-seat passenger or collaborative activities between the driver-passenger pairs. The selected clips were transcribed and analyzed with Nvivo [1].

RESULTS

The trips while navigating to a destination were characterized by active communication and teamwork between the couples while interacting with our prototype. The overall usability of the Co-Navigator was widely accepted by the participants. They referred to it as "*easy to use*", "*very comprehensible*", and "*more clearly arranged compared to a conventional navigation unit*." Others aspects that were highlighted by our participants during the post-trip interviews were that the tablet focuses on the most important issues of navigation. They stated that the bar plot with a defined color scheme was usable to warn the driver about the upcoming demand situations timely.

Eight out of ten front-seat passengers used all four parts of the Co-Navigator (seen in Figure 2) excessively to assist the driver. The map overview specifically (displaying the current location and the driving direction at any time with a red arrow), the three display options (normal, satellite, and hybrid form), and their scalability (i.e., to zoom in and out) were seen by the front-seat passengers as useful for getting a quick overview. For instance, a front-seat passenger described it with his own words: "*It seemed good for me to have an overview of the track and to know where I am. I also like to zoom in and out, as well as to change between satellite and map view*." In the post-trip reviews the couples also emphasized that the bar plot was characterized through an intuitive classification scheme (i.e., red, orange, blue, and white for those section of the trip with no demand situation).

Participants told us that the interaction with our prototype was not only usable but the information was also shown in an appropriate and attractive design. Especially, the cover flow that shows demand situations from various perspectives pleased the couples. Some of the front-seat passengers described them as "*lovely*" or "*attractive*"; others liked the high resolution of the images. Approximately two thirds of the participants clicked at the demand marker to get further information about the upcoming hazards. A main advantage of the prototype was, as mentioned by the participants, that the Co-Navigator not only provided turn-by-turn instructions (in form of arrows accompanied with text) to the front-seat passenger, but also offered the couple the opportunity to have the same information about the current route and, therefore, be able to react collaboratively, especially in harmful situations.

Our data revealed that the placement of the Co-Navigator needed improvement. The unit should be located in a better place in order to provide a better view for the driver and the front-seat passenger. In our study, the mobile unit was not fixed in the car. A mounting solution for the Co-Navigator to be fixed on the dashboard was asked by nearly half of the participants. Concerning the graphical interface of our prototype, four out of ten criticized that the map views are aligned north and are not pointing in the driving direction. This feature, normally provided in conventional navigation systems, was missed.

Three functionalities of the Co-Navigator were especially useful for the shared navigation task. The map overview showing the whole trip was used to get quick overall information. In combination with the upcoming hazard bar, the participants collected information about the future demand situations such as their number, their duration, and their relevance. The color scheme specifically enabled the participants to estimate the amount of assistance needed. If assistance was needed, the images in cover flow style, the third main functionality of the Co-Navigator, were used by 85 percent of the passengers to gather more specific information about a specific demand situation (i.e., position of a pothole).

Seven couples appreciated the various demand situations provided on the Co-Navigator (e.g., bumps, potholes, road constructions, road works, unmarked crosswalks, school buildings, or a kindergarten, a 30 km/h-zone, and a road narrow) as supportive information for finding their way from point A to point B. Additionally, four front-seat passengers stated that custom navigation systems normally give turn-by-turn instructions such as 100 to 200 meters in advance, that make it hard to react timely. In those cases the demand images of the Co-Navigator supported the couple to locate the exact turn, by describing the turns in more detail: "*The turn is over there at the big tree … Then take the turn in 200 meters, first comes the supermarket and then the Alpine Club.*" Other aspects mentioned as relevant navigational information were to have more details about poorly visible crossings, especially in the city, and narrow turns that normally require increased attention of both, driver and front-seat passenger.

In two special cases, two couples that were familiar with our predefined route mentioned that they would also use the Co-Navigator for guiding tourist. Expressed in the words of one front-seat passenger: "*Cool, then I give my husband a small tour.*" He could think of our prototype to be used when they were on holidays. Another front-seat passenger said that he would not use it in familiar areas unless they have visitors in order to offer them an enjoyable experience, underpinned with following statement: "*Maybe for friends or colleagues who visit us. Then I think it is great to have this application. I think our friends would like it*."

Based on our post-trip interviews and observations during the trips we could not find any evidence that the Co-Navigator had a negative affect on the driver's driving performance. Almost three-quarter of drivers perceived the support of the passenger evoked by the prototype as a relief. The additional information (i.e., the map overview, the turn-by-turn instructions, different display options of Google maps, and the upcoming hazard warnings), as emphasized by two drivers, created trust between the couples and provided the necessary reinsurance to the driver. For instance, one driver stated that he would place more trust in the familiar voice of the front-seat passenger than in the voice output of a custom navigation device. Moreover, he estimated that the timing of current navigation devices is often too late and, therefore, as stated in his own words, "*It is very supportive when the front-seat passenger announces the relevant turns explicitly at the right time by saying 'Here, you have to turn'*."

Overall, the assistance with the Co-Navigator through the front-seat passenger was appreciated as supportive by the driver. This is also mirrored with following example: *"I find it comfortable, if I can look on the road and my driving neighbor* (grins and looks to the co-driver) *keeps an eye on me."* All front-seat passengers stated that the Co-Navigator allows to easily share the presented information with their partners.

DISCUSSION

Especially the map overview, the hazard warnings for the entire trip from various directions as well as the provided colored bar helped the front-seat passengers to support their shared navigation (RQ1). We also found out that the participants appreciated the usability and design of our prototype. Furthermore, we indicated that drivers perceived the assistance of the passenger evoked by the prototype as a relief (RQ2). To discuss the results in more detail, we clustered the outcomes of our research in four categories: usability and design, quick overview, shared navigation, and lastly situative context information.

Usability and Design

Statements of the participants during our post-trip interviews indicate that the Co-Navigator had a good usability. This means that our prototype was easy to use and understandable. Furthermore, the level of information was appropriate to support the front-seat passenger. Only relevant context information was shown and the information was reduced to a minimum, where not important aspects were kept apart. Concerning the design of the prototype, the majority of the participants appreciated the placement of the single elements as well as the overall design. Especially, the cover flow visualization, one of the most important functionalities of the Co-Navigator, was used very often to have a deeper look at the demand situations from various perspectives. Having the principle of Google street view in mind, our approach could be one step into this direction for mobile navigation systems. Reducing the high amount of data of Google street view is one key feature in this context. As shown with our prototype this issue could be solved by showing only three different viewing directions (i.e., view to the right/left hand side, front view and detail from front view zoomed in) of relevant road sections, in our case the demand situations.

Quick Overview

The most important aspect of navigation is in the first place to know the current location as well as the near surroundings to generate reference points that could be correlated with the navigation task itself. Therefore, as implemented with our prototype, it is important for future collaborative navigation systems to focus on this basic aspect by providing an overview map with the current position as well as the current driving direction. In addition, a more detailed map can be used by potential "Co-Navigators" (i.e., front-seat passengers) to examine the current surroundings or the surroundings of upcoming demand situations. Taken evidence from our data, the design implication to combine different maps and functionalities was appreciated by most participants to get a quick intuitive overview of the situation in order to help with the navigation task itself.

Shared Navigation

Our study showed that the main functionalities that support shared navigation were the map overview, the upcoming hazard bar, and the images from three directions illustrated in cover flow style. Furthermore, basic information should be given to both the driver and the front-seat passenger to generate a common basic understanding. In our case this basic information was a turn-by-turn information that was displayed on a portable navigation unit for the driver and displayed on the Co-Navigator for the front-seat passenger. Although the detailed information on the Co-Navigator was of great help for the front-seat passenger to assist the driver in the navigation task, the fact that this information was not seen by the driver raised in some cases the discussion of the placement of the Co-Navigator. Some participants were of the opinion, that the Co-Navigator should be placed in a way that the drivers also have the possibility to have a look at it time by time to get detailed information:.

Situative context Information

A main difference of the Co-Navigator compared to conventional navigation systems is the presence of special context information as well as additional information representation. The markers of high demand situations in the birds-eye view map together with the cover flow and the bar with color-coded upcoming hazard warnings enabled the participants to focus especially on challenging situations during the trip. Relevant demand markers, as mentioned by our participants, were bumps, potholes, road constructions, road works, unmarked crosswalks, school buildings, or a kindergarten, a 30-zone, a road narrow, or a poorly visible crossing. Some of these hazards are already included into current navigation designs. Especially, potholes, school buildings, kindergartens, or poorly visible crossings are missed and could be potential scenarios for future warning systems.

Furthermore, the timing of the representation of information is very important for appropriate reactions. This is a major drawback of current custom navigation systems. The time between recognizing and reacting to certain information differs between individuals depending on their abilities, mental state and the current situation. In case of assistance through the front-seat passenger, therefore, the moment in which the information shows up on a collaborative interface has to be personalized and to be situation-aware (e.g., the front-seat passenger is already highly alert before reaching the second pothole). This finding could be used to improve current navigation systems by means of customizing the timing of information representation.

Based on our data, we further suggest a personalized situation- aware system that integrates a precise description of the environment with human-like navigation instructions (e.g., "*Take the left turn in 200 meters, first comes the supermarket, then the Alpine Center*", or "*The right turn is at the big tree*", as named by the co-drivers). The use of this type of description for navigation designs is in contrast to the current navigation systems based mainly upon street names and metric information (e.g., "*Turn left at H-Road in 50 meters.*") that allows drivers to locate an upcoming maneuver. The design challenge of not only using predominantly distance-to-turn information could be addressed by combining metric turn-by-turn instructions with personalized situation-aware landmarks (e.g., "*Take a turn at the big tree.*")

CONCLUSION AND FUTURE WORK

While the field of automotive HCI research focuses on driver-focused navigation design and distraction of the driver, relatively little attention has been given on the front-seat passengers. Therefore, we have developed the Co-Navigator, which assists the front-seat passenger to support the driver in navigation and driving tasks. This was achieved by providing appropriate navigation information to the front-seat passenger, such as overview maps and various landmarks that refer to specific demand situations, classified into various categories.

Using an enhanced kind of in-situ study, we investigated the Co-Navigator by videotaping, observing, and interviewing ten couples. They used the prototype for approximately half an hour. Our study and the initial prototype showed the importance of front-seat passenger assistance while navigating from point A to point B. With our results, we hope to encourage experience designers and AUI researchers to further explore the car as a design space for different kinds of shared navigation activity between drivers and passengers.

So far, our prototype has been applied in a real-driving scenario context, concentrating on the evaluation of the Co-Navigator's feasibility. As a next step, we plan to analyze our video data by using interaction analysis in more detail aiming to investigate how the Co-Navigator is incorporated into collaborative strategies of driver-passenger pairs and how the demand level affects the nature of collaboration.

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REFERENCES

1. NVivo. Retrieved April 24, 2015 from http://www.qsrinternational.com/
2. Barry Brown, and Eric Laurier. The normal natural troubles of driving with GPS. 2012. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI'12), 1621-1630. http://doi.acm.org/10.1145/2207676.2208285
3. Chandrika Cycil, Mark Perry, Eric Laurier, and Alex Taylor, E. 2013 'Eyes free' in-car assistance: parent and child passenger collaboration during phone calls. In *Proceedings international conference on Human-computer interaction with mobile devices and services* (MobileHCI'13), 332-341. http://doi.acm.org/10.1145/2493190.2493207
4. Jodi Forlizzi, William C. Barley,and Thomas Seder. 2010. Where should I turn: moving from individual to collaborative navigation strategies to inform the interaction design of future navigation systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI'10), 11-1270. http://doi.acm.org/10.1145/1753326.1753516
5. Markus Hipp, Florian Schaub, Frank Kargl, and Michael Weber. 2010. Interaction weaknesses of personal navigation devices. In *Proceedings* of the Conference on *Automotive User Interfaces and Interactive Vehicular Applications* (AutomotiveUI '10), 129-136. http://doi.acm.org/10.1145/1969773.1969796
6. Andrew L. Kuhn, Tim Paek, Zeljko Medencia, Nemanja Memoravic`, and Oskar Palinko. 2009. Glancing at personal navigation devices can affect driving: experimental results and design implications. In *Proceedings* of the Conference on *Automotive User Interfaces and Interactive Vehicular Applications* (AutomotiveUI '09), 129- 136. http://doi.acm.org/10.1145/1620509.1620534
7. Eric Laurier, Hayden Lorimer, Barry Brown, Owain Jones, Oskar Juhlin, Allyson Noble A, Mark Perry., Daniele Pica, Philippe Sormani, Laura Watts, and Alexandra Weilenmann. 2008. Driving and 'Passengering': Notes on the Ordinary Organization of Car Travel. *Mobilities* 3, 1: 1-23.
8. Gilly Leshed, Theresa Velden, Oya Rieger, Blazeiy Kot, and Phoebe Sengers. 2008. In-car GPS navigation: engagement with and disengagement from the environment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI'08), 1675-1684. http://doi.acm.org/10.1145/1357054.1357316
9. Andrew May and Tracy Ross. 2005. Presence and quality of navigational landmarks: Effect on driver performance and implications for design. *J HFES 48*, 2: 346-361.
10. Jeljko Medenica, Andrew L. Kun, Tim Paek, and Oskar Palinko. 2011. Augmented reality vs. street views: a driving simulator study comparing two emerging navigation aids. In *Proceedings international conference on Human-computer interaction with mobile devices and services* (MobileHCI'11), 265-274. http://doi.acm.org/10.1145/2037373.2037414
11. Nicole Perterer, Petra Sundström, Alexander Meschtscherjakov, David Wilfinger, and Manfred Tscheligi. 2013. Come drive with me: an ethnographic study of driver-passenger pairs to inform future in-car assistance. In *Proceedings of the 2013 conference on Computer supported cooperative work (CSCW '13)*, 1539-1548. http://doi.acm.org/10.1145/2441776.2441952
12. Christopher D. Wickens and Justing G. Hollands, In *Engineering Psychology and Human Performance*, Prentice Hall, Upper Saddle River, NJ, 2002.
13. David Wilfinger, Alexander Meschtscherjakov, Nicole Perterer, Sebastian Osswald, Manfred Tscheligi. 2013. Passagier Computer Interaktion. Mensch & Computer 2013. Oldenbourg Verlag, München, 313-316.