# Could You Please…? Investigating Cooperation In The Car

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## ABSTRACT
In this paper, we present the results of a study on the perception of driver and passenger when cooperating in the car. An increased feeling of control when handing over responsibility for secondary tasks to the passengers might form a basis for the acceptance of future natural cooperative in-car information systems. Many studies have revealed the potential of involving accompanying passengers, but so far, their ability to support the driver has not been applied practically. We have developed a system to support driver-passenger cooperation and investigated the effect on perceived control and involvement. An application to search for points of interest (POI) was implemented and tested in a user study. Besides the POI task, the driver had to perform a distraction task to simulate a dual task load. We found that, depending on the person who is executing the task (driver or passenger), the respective person feels more involved in the situation. However, the level of control over the situation is increased significantly for both persons when the passenger is supporting the driver by performing the task. Overall, we provide a new design space for interaction areas in the car and highlight the potential passengers offer to reduce driver's load and thus increase driving safety.

## Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – *computer-supported cooperative work.*

## General Terms
Design, Human Factors.

## Keywords
Cooperation, control, involvement, driver-passenger interaction, in-vehicle information systems, touch interaction, large display spaces.

## 1. INTRODUCTION
Today's in-vehicle information systems (IVIS) are mainly designed to be controlled by the driver. However, the cognitive load required for interaction with the IVIS distracts the driver from the primary task, no matter what input modality is used [3]. On the other hand, passengers in a shared ride are free to do whatever they like as long as this does not have an impact on the driver. They can use smartphones to retrieve information, use both hands for interaction and do not need to observe the traffic situation.


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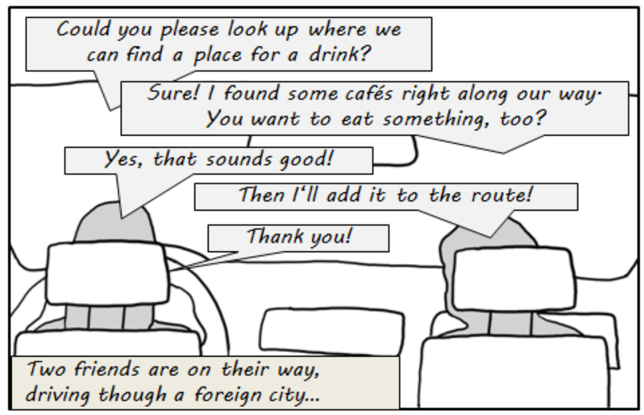


**Figure 1. When driving with passengers, their potential to support the driver often remains unused. We propose to give the passenger a dedicated interaction space, and find that the driver can benefit and gain more control over the situation.**

We suggest letting the passenger support the driver by carrying out a main part of the interaction with the IVIS (Fig. 1). This can potentially disburden the driver but might also conflict with existing habits and make the driver feel cut out. We conducted a qualitative study to test the acceptance of transferring responsibility to the passenger. The task was to find POIs in a map-based application while the driver was performing a distraction task. We found that, depending on who is performing the task, the active person feels more involved in the situation. However, when the passenger is interacting, the feeling of control can be increased for both. Moreover, we found that for the design of cooperative systems, it is important to avoid additional distraction of the driver by the actions of the passenger. Our findings suggest that it is worth the effort to design cooperative systems to enhance the driving experience for all parties.

## 2. RELATED WORK
There has been a vast amount of research that investigated the driver-passenger situation in the car. Regan and Mitsopoulos [10] highlight in their report on behavioral interaction between drivers and passengers that there is an influence on vehicle safety when a passenger is present. Especially for young drivers and male passengers, this effect can be negative when drivers want to prove themselves; however, the authors also highlight the potential of the "extra set of eyes" that drivers might benefit from. Forlizzi et al. [1] investigated the social aspect of in-car interaction with a focus on navigation. They recommend to adapt human-machine-interaction to inter-human communi-cation (i.e. customize information context-dependent and to prior experiences). This is still difficult, despite the growing amount of available information and thus points towards "making use" of the humans themselves

in shared rides. Gridling et al. [2] conducted an obser-vational study and found that passengers already help the driver, e.g., to gather information, and that trust is a main factor that influences the collaboration between driver and passenger. They recommend providing different information depending on the person who is interacting. Similarly, Laurier et al. [6] analyzed several video-recorded trips with a variety of backgrounds, social and technological. They state that *"passengering"* is often more than just being driven from A to B. They often get involved in the demands of driving the vehicle, and thus can be seen as some kind of "crew-member". Inbar and Tractinsky [5] pointed out that the interaction between driver and passengers can potentially improve travel safety and experience, and suggest to support the sharing of information. Thereby they raise the question of "How [can] drivers transfer some of their tasks to passengers, while remaining in control?" Perterer et al. [9] suggest to better integrate the passengers, especially the front-seat passenger, by providing them with a dedicated interaction space. They report a study where a split view on navigation data, realized with both a navigation device and a smart phone, helped to cope with a critical situation by allowing the passenger to search for further information while the driver was still provided with an overview over the situation. Further developed as one system, it can help to integrate additional content of a passenger-dedicated interaction space into the driver's view as needed. Moreover, it can help to monitor car-related information without disturbing the driver's interaction space.

# 3. DESIGN SPACE

Large touch screens have been used in concept cars for a while, and with the recent release of Tesla's Model S[1] there is now a car in the market that makes use of a large interactive surface integrated in the cockpit. In a next step, this display area could be extended towards the passenger's side. Concept cars like the Toyota Fun Vii[2] even integrate the rear seat passengers in a shared display space. Scott [11] observed the social behavior when interacting together on shared workspaces and found that dedicated spaces for individual and cooperative work are created to coordinate collaboration. People tended to perform a task in a personal space right in front of them, while shared spaces were used when interacting together.

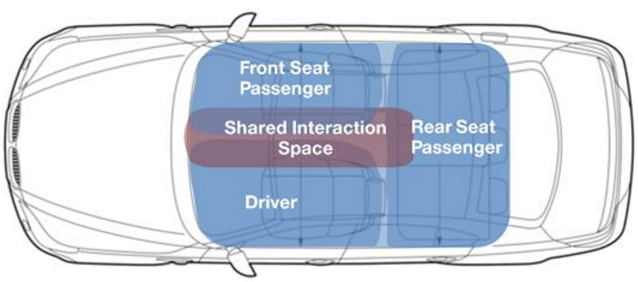


**Figure 2. Design space areas in the car (driver, front seat passenger and rear seat passenger) - in combination with a shared interaction space (adapted from [7]).**

We wanted to transfer this principle to a problem solving task in the car, in which driver and front seat passenger have their own interaction space, but also a shared space to collaborate. On the driver's side, the dedicated space can be the instrument cluster or a head-up display (HUD) that can be used for car-related information. Those are not suitable for direct interaction, so driver input has to take place on the steering wheel or in the center console region. The passenger has no restrictions regarding the in- and output modalities. Both hands can be used, and full attention can be turned towards the interaction. A shared space needs to be placed in reach for all parties; therefore a suitable space is the center console. Traditionally, radio and climate functions are located here to ensure direct access of both driver and passenger. We took the approach of Meschtscherjakov et al. [8] and adapted their design to extend for a further design space in the car integrating shared interaction (Figure 2).

# 4. INTERACTION DESIGN

We conducted a workshop to assess potentially meaningful situations and use cases for driver-passenger cooperation. We decided for tasks to support way finding on a shared trip with friends. There are many other tasks a passenger can perform, like reading and writing emails, online search etc. However, to provide additional benefit and not introduce more distraction than necessary, the following three tasks were chosen. All of them are already possible with the functionality current IVIS or smart phone apps offer, but shall now be integrated in one system.

*BankFinder* and *BarFinder* are designed to be used by either driver or passenger to display the respective points of interest on a map. Further details like opening times or ratings are displayed in a pop-up. *TourPlanner* is a joint sightseeing application that can be used to set up a route along various points of interest. The passenger is able to get a more detailed view, whilst the shared screen gives an overview over chosen POIs, and the possibility for all parties to rearrange them (Figure 3).

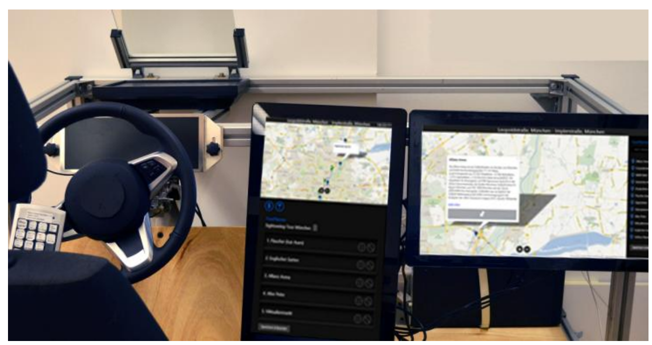

**Figure 3. Hardware setup of the user study, running the *TourPlanner* app. Left: The shared view in which both driver and passenger can adjust the tour. Right: Passenger view that includes more details and more possible interactions.**

# 5. USER STUDY

To investigate the influence of a supporting system on the perception of control and involvement, we conducted a user study integrating driver and front seat passenger.

## 5.1 Participants

Eight groups of two people took part in the study (4 women, 12 men, mean age 28). All of the pairs knew each other beforehand. Friends and colleagues are reported to be the largest group of passengers after spouses and children, whereas foreigners only play a minor role [10]. 56% prefer to take the role of the driver, while the others prefer the passenger's role (13%) or are indifferent. The roles for the study were assigned randomly. All participants are driving in a car at least once a week in both roles

[1] http://www.teslamotors.com/models

[2] http://www.toyota.com/letsgoplaces/fun-vii-concept-car/

and use touch interaction on smartphones or tablets in their daily life. For details on the apparatus see Figure 3.

## 5.2 Apparatus

The hardware setup (Figure 3) consists of a steering wheel, a car seat for the driver and an additional chair of equal height for the passenger. Two 22’’ multi touch capable displays (Iiyama ProLite T2233MSC) were attached to form the central, shared information display and a front seat passenger information display. A 17’’ display (Asus VB175T) and a mirroring glass plate were used to imitate a HUD. The instrument cluster display was not used. Additionally, a numpad (Keyboard KL-368) was attached to the left side of the steering wheel, so the driver’s primary task could be performed with her left hand.

## 5.3 Experimental Design

The first part of the study used a within-subject design with the two levels *driver* and *passenger* for the **executer** performing the task. The used **app** (*BarFinder* or *BankFinder*) was counter-balanced. In the second part, driver and passenger were using *TourPlanner* together to reveal insights into their behavior when performing a more complex task. A simple distraction task was deployed to keep the driver’s attention on the simulated HUD, i.e. the area where attention on the road would take place. Similar to a lane change task, where drivers are asked to change lanes depending on signs along the road [7], drivers had to respond to highlighted arrow signs as fast as possible on a numpad attached to the steering wheel (Fig. 4). We measured the driver’s distraction with both reaction times and interview questions. Moreover, we used questionnaires on perceived usability (SUS) and experience (AttrakDiff). In between the tasks and afterwards, we conducted semi-structured interviews to assess subjective feedback on involvement and feeling of control.

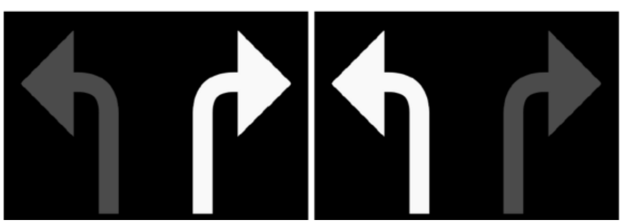

**Figure 4. Arrow signs the driver had to respond to as a means of distraction to simulate a primary driving task.**

## 5.4 Study Procedure

Participants took part in the study in groups of two. They were introduced in the scenario, driving together in a foreign city, and in the main functionalities of the integrated system on the two screens. The driver was introduced in the distraction task and performed a test run. The study began by starting the distraction task, and the experimenter gave the driver the instructions to find either a bar or bank with specific properties along the way, to be forwarded to the passenger. After both parties had executed the tasks, they were instructed to put together a tour for the next day, containing five sights. During the study, the experimenter was present to answer questions, observe unusual behavior and record comments.

## 5.5 Results

All results are reported at a significance level of .01. Subjective results are based on 7-point Likert scales.

After each task was performed by either driver or passenger, both were asked how they **perceived** their **control** over the situation. This was specified to include both primary and secondary task. Results in Figure 5 show that the driver feels disburdened when the secondary task is fulfilled by the passenger. We observed that performing both primary and secondary tasks led to confusion and errors of the driver, while no errors were apparent when the passenger was interacting. On the other hand, the passenger feels much more integrated and thus in control. Moreover, the imbalance between the perceptions is neutralized. Therefore, we conclude that letting the passenger execute tasks can significantly enhance the feeling of control for both parties, while having the driver taking all the responsibility does not only make him feel less in control, but also creates a situation of disparity, as ratings of driver and passenger were only significantly different when the driver was executing.

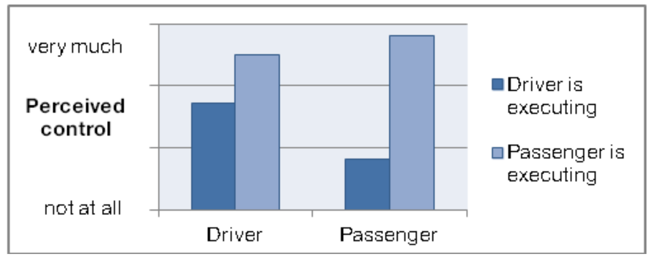


**Figure 5. Perceived control (*“Did you feel you could control the experienced situation?”*)**

When performing the *TourPlanner* task together, both had a high feeling of control, indicating that not only the direct interaction with the system is important. Browsing details of POIs was mainly performed by the passenger, but when analyzing the comments, it seems that the driver feels to have a direct influence because of the shared discussions on the results and the possibility to step in the final selection and arrangement in the shared interaction space.

A further question after each condition was, how **involved** in the current action driver and passenger felt (Fig. 6). Using *BarFinder* and *BankFinder*, the respective executer experienced a higher involvement when performing the task. This difference was not significant. Regarding the *TourPlanner*, both parties rated the involvement equally high. Even though the passenger took the main part of the interaction, common discussions on the shared goals raised the perceived participation for the driver.


**Figure 6. Perceived involvement (*“How involved did you feel in the experienced situation?”*).**

**Fehler! Verweisquelle konnte nicht gefunden werden.** shows the reactions times as a measure of **distraction** while performing the primary task for the different tasks during the study. The driver reacted significantly slower to the arrow signs when he was performing the task than when the passenger was interacting. In the shared task (*TourPlanner*), when both parties were interacting, only a slight increase was observed. The driver was also asked to rate the perceived distraction of the primary task. The results support the measured reaction times.

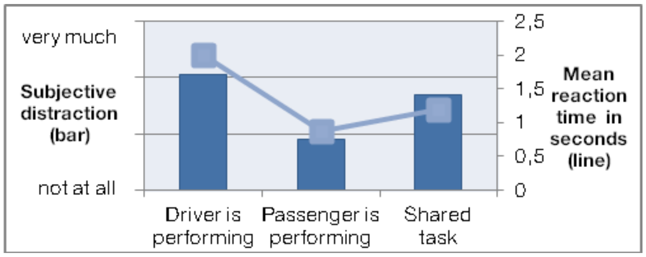


**Figure 7. Mean reactions times (in sec) and perceived distraction in the primary task (*"As how exhausting did you perceive the distraction task"*) (drivers only).**

The SUS showed high ratings for both driver and passenger. Using the AttrakDiff, we assessed the **hedonic and pragmatic quality** of the overall system (Figure 8). Pragmatic quality was rated high so we con-clude the functional goals that emerge in a cooperative task are well supported. By providing the passenger with more information than the driver could handle, overall functionality can be increased, while an over-view over the current status is constantly accessible for the driver. The hedonic rating shows a high value, yet there is room for improvement. Due to the study setup, participants mainly fulfilled their behavioral goals [4]; further experience with the system would be needed to investigate the impact on hedonic quality.

We **observed** that people, especially the drivers, wanted to know what the passenger was doing. Most of the people started commenting on their current actions to keep the other one informed. Otherwise, the drivers sometimes neglected their primary task to sneak a peek on the passenger's display. We conclude that it is important that the driver is not distracted by what the passenger is doing, but should always be informed about the current status. Tang [12] has highlighted that in a collaborative environment, everybody should be able to observe the current status. This can for example be achieved by constantly displaying high-level results of the passenger's interaction to the driver.

# 6. DISCUSSION AND LIMITATIONS

We observed a positive effect of integrating the front seat passenger into the execution of tasks related to the current driving context. Perceived control over the situation was raised for both parties when the driver concentrated on the primary task and the passenger performed additional secondary tasks. Carrying out the study in a lab setting made it possible to control the primary task's difficulty and thus to compare the results of the different conditions. However, a real driving task, where the distraction level changes constantly, might influence the results. A further interesting aspect would be to investigate the impact of different levels of complexity of the secondary task. A more complex secondary task could increase the willingness of the driver to hand it over and foster discussions. Further experience and easiness of exchanging information might also increase the acceptance of cooperation.

# 7. CONCLUSION

In this paper, we investigated the design space of shared interactions in cars by taking additional persons in the car into account. The results show that handing over tasks to a passenger does not degrade the driver's feeling of control for the overall situation but can actually increase it when demanding primary tasks claim the attention. On the other hand, the disparity of perceived control when the driver performs all upcoming tasks can be resolved when the passenger is actively involved. In summary, we encourage researchers to design IVIS to make use of all available cognitive capacity in a car. This can decrease driver distraction without decreasing the feeling of control.

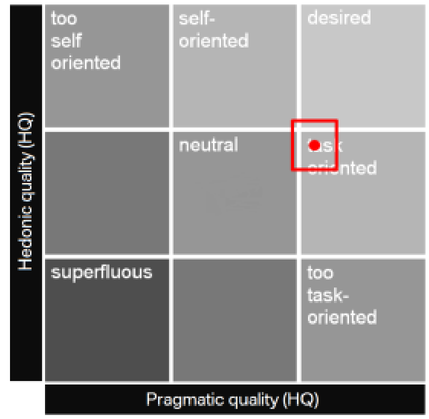


**Figure 8. Perceived user experience.**

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