Abstract
Modern cars are a good example for ubiquitous computing, they are pervaded by interactive technologies. Most of these systems add new interface elements, clustering the car with knobs and touch screens. Our approach is to take advantage of physical structures and affordances of existing tangible objects in the car (e.g., handles) and use them as controllers for in-car gaming. By augmenting these elements with computational properties, we aim at transforming them into input modalities. We present CarTeam, a collaborative multiplayer game that uses tangible elements in the car as input devices. We conducted an exploratory study through game sessions and gained information on social processes in the car, the game design itself and on the augmented tangible elements. Our findings are a first step to inform the design of collaborative in-car games. We aim at helping designers and researchers to rethink the car as a space for new kinds of automotive gaming applications.

Author Keywords
Automotive Gaming; Tangible Interaction; Games; Collaboration;

ACM Classification Keywords
H.5.m. [Information Interfaces and Presentation]: Miscellaneous
Introduction
Gaming in the car is able to enhance passengers’ experiences and reduce frustrations while driving. Most concepts, such as video game consoles or smartphone applications, do not take advantage of the specific properties of the automotive context to enhance the gaming experience. Even games that make use of the car context in a novel way rely on adding non-car specific interactive systems to the passenger compartment [1, 2].

We see the car as an environment rich in tangible, interactive elements. The traditional tangible elements as well as the physical structures in the car have yet to be considered for meaningful interaction with computer systems. Instead of introducing new devices into the car, we want to explore gaming in this context by augmenting its native interactive elements with computational properties.

Following the approach of Schmid et al. [4] of inverting the design process to inspire the implementation of tangible interactions, we used the properties of the car’s inherent interactive elements as starting points for our design process. Based on the idea of tangible bits by Ishii and Ullmer, [3] we saw the car specific hardware as fertile ground for the implementation of various tangible input devices. The combination of the car design space and gaming has been exemplified by Thijs Eeren’s Park to Play, which shows how to use the car as a game controller1. Based on a collaborative game taking place in trams, Toprak et al. [5] provide guidance regarding limitations and challenges for designing games in unconventional places such as transportation. We applied this thinking to the car design space, taking the potential limitations and challenges into consideration.

The goal of this project was to explore the design space of the car, as well as its social and collaborative aspects. We did this, in order to better understand the car and its interactive elements as a space for collaborative gaming. Thereby we deliberately did not restrict ourselves by taking into account safety issues. In the following we present our design process. Then, we outline the game concept to provide an understanding of the approach. Thereafter, we describe an explorative user study and provide findings.

Design Process
To get a better understanding of the car as a design space and its inherent characteristics our first step was to explore which input modalities a potential gaming application in the car could use. Thus, we conducted an explorative workshop in a real car to find ways of tangibility in the car specific interfaces and how we could use them in a collaborative game setting. Four researchers took a trip for approximately an hour noting all reachable interactive elements from their seats. Afterwards we aggregated our notes and discussed our findings, which lead to a categorization of car interfaces. It included the three characteristics accessibility (e.g., available only for the driver like the steering wheel), tangibility (i.e. potential physical representation of digital information), and state (e.g., the difference between a switch that can either be “on” or “off” and a handle that can be in different angles). These characteristics served as a basis for the design process of the actual interfaces we used for the game. We interpreted the interfaces from the perspective of their potential output datatypes (e.g., handles can be in different angles and therefore would output a value representing this angle). We identified two types of data: “range”, which is a discrete number value in a certain range, and “boolean”, which is “true” if

---

1http://thijseerens.com/
something is in a certain state or “false” otherwise. Based on that, we further distinguished the aforementioned state property as persistent or non-persistent. A persistent input device does not change its output unless moved (e.g., a switch stays on if pressed) whereas a non-persistent input device always switches back to a default value when it is not in use (e.g., the angle of a grab handle returns to 0 when released). Based on these reflections we developed a game concept.

**Game Concept**

The game idea takes inspiration from a cooperative mobile game called Spaceteam\(^2\). Spaceteam connects several smartphones or tablets giving each player a control panel with several input modalities, such as buttons and sliders, as well as an instruction panel. Players receive commands on the instruction panel. These commands have to be executed using the available input modalities. Commands are usually not for the player to whom they are visualized, but dedicated to teammates. Thus, players have to communicate and work together with their teammates to execute the instructions correctly. We chose Spaceteam as it demonstrates how gaming, collaboration and using different input elements can be combined in a simple and entertaining way.

We implemented Spaceteam’s core mechanics within a car simulator (see Figure 2) with four players as part of the team (i.e., the driver, the front-seat passenger, and the two back seat passengers). Each team member has to fulfill certain tasks mapped to their seat position. For example, the player sitting on the left back seat gets the command “The front-seat passenger, must fasten the seat belt!” Commands have to be executed within a certain time frame in order to win the game. Each team member (except the driver) has a display mounted in front of their seat which shows (i) the current command (for either themselves or a teammate), (ii) the remaining time for executing the command, and (iii) a feedback indicator for successful or unsuccessful execution of commands. The driver and the passengers have to talk and collaborate to succeed. Figure 3 illustrates this collaboration.

![Figure 3: Seat specific inputs and In-Game collaboration via talking. The example illustrates a task prompted to the right front seat requesting persons in the back to execute a command (i.e., feet down).](http://www.sleepingbeastgames.com/spaceteam/)

When designing the game we intentionally included the driver as a team member neglecting driver distraction. This was necessary to get a complete impression of the space of the car’s passenger compartment. Moreover, in future autonomous driving concepts the role and the tasks of the driver might change significantly when the primary driving task is omitted.

Bringing the Spaceteam idea into the car made sense as its inherent interaction metaphors, like activating switches and pulling handles enabled us to freely apply these output datatypes to the different input modalities and create a contextual game setting. Therefore we were able

\(^2\)http://www.sleepingbeastgames.com/spaceteam/
to use the property of a range value output on different interfaces like the steering wheel or the angle of the handle position in a similar manner. Based on the categorization from our workshop we finally chose the interfaces we then used for the game.

**Technical Setup**

As a prototyping environment an in-house car prototyping simulator was used (see Figure 2). To connect the various parts of data producers and consumers together we used Spacebrew\(^3\). Spacebrew is an open source toolkit to create interconnected applications. To make the car hardware available as input devices we used several sensors driven via Arduino UNO microcontroller boards\(^4\). To simplify the setup and create interchangeable bits, we connected the microcontrollers via Ethernet. The Arduinos connect to a Spacebrew server and offer data with either a "range" or "boolean" data type.

The game logic is handled by a game master, an application which acts as the central input and output hub of data. It is responsible for creating the commands for the various inputs, dispatch them to the displays and to check for successful execution or time out of a command. Each display shows a Processing\(^5\) sketch that receives data from the game master and displays the command text, a timeout bar indicating how much time is left to execute the command and a feedback symbol to show whether the current command has been successfully executed.

**Input Devices**

Our game prototype used the following car hardware as input devices (also see figure 1): (i) **Steering wheel and driving input** from the car simulation software (data: range, e.g. steering angle or speed). (ii) **Seat belts** as car specific wearable interfaces. Buckling up and unbuckling acts as a switch (data: boolean, on/off). (iii) **Handles** on the car’s ceiling (data: range, angle of handle) (iv) **Foot mats** detecting when the feet are on the ground (capacitive sensing via aluminum foil under the mats) (data: boolean). (v) **Headrests** on the front row detecting a touch from the back-seat passengers (data: boolean).

**Explorative Study**

We studied our setup and design in explorative gameplay sessions with a changing set of 4 players (12 participants in total; 1f, 11m) inside our car simulator. Participants were assigned to their seats and given a short description of the game and their controls. The game was played during a simulated driving situation on a test track in the driving simulator to achieve the feeling of a driving car. The sessions were recorded on video for later reviewing. Afterwards the players were asked about their opinions on the interaction and interfaces in informal interviews.

**Study Findings**

Observing and inquiring the players gave us many insights about the game and our research questions.

**Game Concept**

The players found the game entertaining and engaging. Most of them wanted to play more game sessions so they could experience the game from all different seats. A crucial factor of the game and its interactions was the tempo in which the commands were prompted. As the tempo of the game increased (by prompting commands more and more frequently) people found it harder to successfully execute the commands. This lead to a more
rushed way of using the interfaces like sharply pulling the handles. By gradually learning how the inputs and commands are connected, people tended to optimize their interaction with the inputs by preparing for possible future commands by for example unbuckling the belt only halfway. At first players simply repeated the given commands literally (e.g., "Lift feet at the right back-seat!"). Soon, they changed to direct commands (e.g., "Player X, lift your feet!").

Overall players wished for more information about the game state, like who is responsible for timed out commands and who was the best at executing commands, which could possibly break the collaborative aspect of the game. In a next iteration we will dynamically adapt the game play tempo and visualize the game state more explicitly.

**Collaborative gaming and its social implications**

The game helped us to better understand the social processes in the car that came up during the gameplay sessions. Gaming with each other in the car somehow transformed the space of the car and how it was perceived by the players. This was something that people were very aware of. Especially the meaning of the seats and their positions changed.

The different sets of players found their own way of communicating and working together. Some played rather active and loud, others played organized and calm. The seating position was the most influential factor on how players played the game. The persons sitting in the back-seats found it easier to relay their prompted commands to the specific people with the corresponding inputs, some even tapped their teammates on the shoulder or head. Conversely the persons in the front row often had to actually turn their heads around to make their voices heard. They were also more likely to report that sitting in the car is perceived as being "locked" in a certain spot. Often one player would emerge as a leader who would make sure that the whole team executes the commands right. This role was usually held by persons sitting in the back. Players reported a feeling of working together and actually being a team due to the confined space of the car simulator.

**Tangibility of interactive elements in the car**

The analysis of the gameplay sessions lead to a different view of existing hardware in the car. For example, the input from the handles was actually perceived as being a boolean switch. Even though the handle offers movement through a range of values, players experienced the handle as a binary controller. One used the handle by grabbing and pulling down until one could relax the muscles of the upper arm. If the handle should be used to differentiate between the possible angles, players would wish for more haptic feedback (e.g., resistance against moving it in the desired direction).

People also found it hard to bring the handles into a specific position as instructed by some commands. Which means commands like "Set handle to 100!" were more difficult to accomplish than others. Thus, the resolution of commands has to be adapted to the context (e.g., "Pull handle half a way!"). Because of the collaborative aspect of the game people talked a lot during the game about how the specific interfaces had to be used to fulfill the commands. They practically learned to use the interfaces and reinterpret them in a new way together.

The time aspect of the game led to a certain stress factor for the players that made the affordance and mapping of the interfaces to specific functions even more important.
Overall, the players perceived the car as a game controller and were surprised by how using the interactive elements in a game changed their perception of them. One player reported on their previous embodiment of the interaction: "I can’t tell how many times I have used this element before. It’s interesting to get a new perception like this."

**Technical Setup**

The usage of Spacebrew, Arduino and Processing proved to be very suitable for rapid prototyping. Breaking down the game components (i.e. sensors, displays, game master) into interchangeable bits, interconnected by Spacebrew, allowed us to constantly improve on a working prototype. We were able to test the various input modalities independently from the game as well as to rapidly change the setup for the game.

**Conclusion and Future Work**

We demonstrated CarTeam, a collaborative game that uses the car as a controller. We investigated the tangible interactive elements in the car and used the car as an unconventional social gaming space. The game setting helped us to better understand the design space of the car, including characteristics of its tangible elements.

Our findings can contribute to the design of future in-car games. As an example, the meaning and function of the seat position and the respective communication between players are closely related to safety concerns, for instance when players aim to touch each other during gaming. We aim to further develop game concepts that incorporate those findings into new ways of interaction.

Our research also showed that there are many preconceptions and embodiments in peoples’ thinking, which makes it harder to introduce new interaction concepts and perspectives into the car space. This is due to the fact that the car hardware is already well-known.

Our research acts as a first step in better understanding physical structures and social gaming practices in the car. In our future work we want to further develop and understand the car design space and use our findings for designing future collaborative in-car games.

**Acknowledgements**

The financial support by the Federal Ministry of Economy, Family and Youth, and the National Foundation for Research, Technology and Development is gratefully acknowledged (Christian Doppler Laboratory for Contextual Interfaces).

**References**


