



Department of Electrical Engineering and Information Technology
Institute for Media Technology
Distributed Multimodal Information Processing Group
Prof. Dr.-Ing. Eckehard Steinbach

Gamification of Automotive User Interface Exploration

Duc Ha Minh

Diploma Thesis

Author:	Duc Ha Minh
Address:	[REDACTED]
Matriculation Number:	[REDACTED]
Professor:	Prof. Dr.-Ing. Eckehard Steinbach
Advisor:	Prof. Dr. Matthias Kranz Dipl.-Ing. Stefan Diewald
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Department of Electrical Engineering and Information Technology
Institute for Media Technology
Distributed Multimodal Information Processing Group
Prof. Dr.-Ing. Eckehard Steinbach

Declaration

I declare under penalty of perjury that I wrote this Diploma Thesis entitled

Gamification of Automotive User Interface Exploration

by myself and that I used no other than the specified sources and tools.

Munich, 29.11.2013

Duc Ha Minh

Duc Ha Minh



Kurzfassung

Fahrzeuge sind heutzutage multimediale Umgebungen, die dem Fahrer mehr bieten als nur den Transport von A nach B. Eingabeelemente vereinen daher oft mehrere Funktionen gleichzeitig um die steigende Anzahl von Funktionen abzudecken. Der Fahrer verliert dabei den Überblick über weiterreichende Möglichkeiten, die ihnen das Fahrzeug bietet. Das Wissen der unbekannten Funktionen wird dabei nur selten durch Konsultieren des Benutzerhandbuchs erworben.

In dieser Arbeit wird das Konzept einer mobilen Anwendung und dessen Implementierung für Android Geräte vorgestellt, die mit Gamification Elementen helfen soll, den Verbraucher dazu zu motivieren, sich mit der Benutzeroberfläche seines Fahrzeugs auseinanderzusetzen. Dabei werden Benutzerstudien analysiert, die sich mit der Bedienung von Eingabegeräten im Fahrzeug beschäftigen. Zusätzlich wird die Theorie der menschlichen Motivation eingebunden und geläufige Definitionen der Gamification untersucht. Die Arbeit beinhaltet zudem den Versuchsaufbau und Ergebnisse sowie Analyse des Experiments zum Testen des Prototyps. Letztendlich werden Vorschläge zur Weiterentwicklung des Konzepts erstellt.

Abstract

Vehicles have evolved to multi-medial surroundings that provide more than just transportation from A to B. Input elements often have to combine multiple functions at once to cover the rising number of features. It is easy for the driver to lose track of the entirety of operations that the vehicle provides. The knowledge of these features is only rarely acquired by consulting the user manual.

A concept for a mobile application and its implementation for Android devices is thus presented in this work. The application is supposed to motivate the user to engage with the vehicle user interface by implementing Gamification elements. To this outcome, the work analyses behaviour studies on vehicle operation. Additionally, the work includes the theory on human motivation and examines current definitions on Gamification. The setup, as well as results and analysis of the experiment to test the prototype of the mobile application are presented and proposals for further development are given.

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Chapter 1.

Introduction

Cars have long surpassed the status of mere means of transportation. With the increasing computing abilities of modern devices as well as the high demands of modern society, they have become a second living space for daily drivers. To decrease the boredom of the routine driving task, car manufacturers install an increasing number of infotainment and entertainment systems in the cars. Next to these entertainment systems, cars also hold a growing number of driver assistant systems to take off a part of the driver's mental workload and increase safety.

1.1. Motivation and Goals

With the rising number of systems built in a car, also the number of control elements increase. Studies on in-car operation behaviour of drivers have shown that even proficient vehicle users don't know all functionalities of their vehicle. This means that they spent money on features that they do not know or use. Next to this loss in a financial point of view, the ignorance about the wholesome of a vehicle could pose a safety risk, as the driver may not be able to react to hazards when they are not perfectly familiar with the car. Even though certain driving tasks remain the same with each car, the in-car design differs in certain details. Especially in case of car sharing or car rentals, drivers are prone to operate a model, which they are not familiar with.

There can be many reasons for not getting to know the vehicle functionalities better, but some of the main reasons that are being named, is the lack of time and the lack of motivation.

This work will try to deal with both problems by proposing a mobile application that will educate the driver of the in-car operating possibilities. As mobile devices nowadays such as smart-phones and tablets are spreading widely and possess high computer performance, they are an ideal complementation to the in-car's systems without having to install further hardware [1, 2]. The concept for the application will be designed with the theory of gamification, adding game elements to an application that is not designed in a game context.

Since the term gamification has come up in 2008, it has been steadily growing as a supportive system in all aspects of every day life. The theory behind gamification states that game elements such as points and badges give the user a motivation to acquire new achievements and comparing and competing with similar users. This work will take up on the theory and explore the possibilities of implementing a mobile application that will educate the driver about in-car functionalities and provide necessary motivation through game elements for time-limited professionals to utilize the application.

1.2. Outline of the thesis

The remainder of this work is as follows. Chapter 2 starts by assessing the operation behaviour of vehicle users. The assessment will be used to find out, which user group to target with the application as well as which functionalities in the car are likely to be unknown to, or unused by drivers. Next, the chapter takes up on the basic theory of involving fun and motivation in task execution to examine the roots of the Gamification theory. Lastly, the chapter analyses recent gamification theory and proposed elements by proficient members of the gamification community as well as gives examples of existing gamified applications. Chapter 3 takes the results from Chapter 2 to form the concept of the mobile application as well as its specifications. The technical aspects of the implementation of the concept towards a draft application are explained in Chapter 4. Chapter 5 deals with the approaches for the evaluation of the implementation and the results of the evaluation are presented in Chapter 6. Chapter 7 concludes with an outlook on further upgrades of the application and its possibilities both for vehicle users as well as manufacturers.

Chapter 2.

Research Towards Developing a Concept Model

2.1. Assessment of Vehicle Functionality and Driver Behaviour

The first step we take in the preparation of forming a concept for our mobile application is to assess which functions and which user group to address with the application. For this, we build up on results of automotive user interface studies as well as the user behaviour on vehicle operation.

In their paper, Kern et al. analyse the in-car design space for the driver-based automotive user interface [3], which we will take up on. They state that the amount of functions which a user can control while driving has greatly increased in the recent years. The reason they see for this trend is that the car is evolving from a means of transportation to a multifunctional living space. One reason for this development can be seen due to the rising number of vehicles on the streets and improving infrastructure that make it necessary for many people to spend one hour or more per day in their car. To make the daily commute a less boring routine, car manufacturers include an increasing number of info- and entertainment and comfort systems as well as driver assistance. This trend supports the hypothesis that the car is developing into more than a means of transportation.

For our application, we assume that most drivers are oblivious to a number of the functionality that their car provides. We will support our hypothesis with studies on user behaviour on vehicle operation, with the main focus on Sacher's dissertation [4].

Three Task Class Model

Commonly, the functionalities available to the driver are divided in three classes by Geiser [5]. The primary tasks describe all activities that the driver performs for manoeuvring the car longwise as well as in transversal direction. This includes the steering itself as well as accelerating and

braking. Secondary tasks complement and support the primary functions and increase the safety of the driver, the car, and the environment. This includes the operation of signalling, the wind-shield wipers, clutch, and gear selection. Although not directly a secondary feature, the operation of the navigation system as well as the distance regulation is counted as part of the secondary tasks, as they influence the driving performance. Tertiary tasks do not affect the primary tasks; they are connected to improve the quality of the driver's convenience. The tertiary tasks include operating entertainment and infotainment equipment such as the stereo, the audio and climate control, or the telephone.

Mental Workload of Multiple Task Execution

Even though tertiary tasks can be seen as not essential to the operation of the vehicle, they influence the driver and thus the quality of the operation of the vehicle. Lansdown et al. [6] examined the mental workload of the driver when facing multiple simultaneous tasks and connected their results to possible safety impairments of operating secondary and tertiary tasks. In a high fidelity driving simulator, they assigned tasks where the driver was confronted with displays of numbers and letters on a screen during the drive. The task for the driver was to push certain buttons to confirm the display as soon as they felt it safe to operate the second task. Compared to the control task where the drivers should operate the car under normal circumstances, the results show that secondary and tertiary tasks have a significant influence on the driver. During the experimental tasks, they recorded that the headway decreased compared to the control task and the brake pressure increased. To compensate the increased workload of a secondary task, the drivers reduced the speed of the vehicle. Although the experiment is not directly related to routine driving, it can be translated that interaction with secondary and tertiary tasks in a moving vehicle increases the mental workload and thus influences the driver's attention on operating the car. Lansdown et al. [6] conclude that unquantified safety risks can occur due to the increase of the mental workload.

Automotive User Behaviour

This conclusion will be taken as guideline for the conception of the proposed application. The application will need to be designed to train the driver into avoiding elevated mental workloads while driving by increasing the driver's proficiency in operating the in-car functions. To assess which functionalities the application will address, we take a closer look at Sacher's dissertation [4]. The experiment in Sacher's work was carried out as a naturalistic driving study with the goal to observe the operating behaviour of drivers in their normal environment. For this kind of study, the driver is observed for a longer period of time without a specific task assignment to capture the driver's behaviour in their daily routine. The drivers were given a test vehicle that was identical to their own

car and observed over a period of one week. The two test vehicles were an Audi A8, vintage 2002 and an Audi A6, vintage 2005 with standard interiors with infotainment system, Adaptive Cruise Control (ACC), multi-function steering wheel and automatic climate system. Furthermore, for the experiment, the test vehicles were equipped with a data logger to monitor the communication in the on-board BUS system.

Prior to the experiment phase, the participants filled out a general questionnaire to assess their subjective perception on their driving and operating behaviour and were invited to an interview to answer additional questions to analyse the motivation and preferences for their vehicle handling and their awareness thereof. From this data, the participants were grouped according to the car model, their age, driving style, interest in technology, and the usage of the vehicle and its operating elements.

The experiment focuses on the participants' knowledge about ACC and infotainment. The level of knowledge was also analysed during the interview, during which the participants stated to be familiar with the functionalities, but also have a lack of knowledge concerning basic functions, as those are rarely used. Knowledge on functions is usually acquired by trial and error, most participants stated that they only consult the vehicle manual if there are warning signs. The reasons for this lack of knowledge are lack of time, lack of interest and, supporting the hypothesis of the gamification theory, the lack of playful interaction.

The results of the experiment show that drivers operate two functions per minute on average. These operations are evenly split in secondary and tertiary functions. The primary functions were not recorded separately. The biggest part in the secondary task operations is made up by signalling, followed by the ACC controls. Experienced drivers usually operate the signalling process without having elevated mental workloads though, as long as the position of the lever is known. The operation of the ACC shows differences between expert and novice users. Novice users are not as proficient in the operation methods and cannot assess the most efficient use of the system. They have more interactions with the system and thus are distracted more often. The operation of the ACC can be seen as an example that drivers are prone to more frequent operations of secondary and tertiary tasks if they are not familiar with the connected functionalities and operation methods in the car.

This phenomenon is even more visible when considering the tertiary functions. Due to the growing number of interdependent functions in the car to assist the driver and increase the comfort, one-to-one mapping of functions to operations is no longer possible. The trend of operating concepts is to decrease the number of input elements and combine various functions to a single input element. Audi's MMI, BMW's iDrive and Mercedes' Command are examples for input elements with multiple functions. These input elements often have different ways of operation, e.g. turning, short pressing, long pressing or tilting. This variety of operating methods for a single input element leads to the driver often not being aware of all available possibilities. Next to the trend of combining

multiple functions into one input element, certain functions can be operated from multiple input elements, e.g. volume control both on the middle console as well as the multi-function steering wheel. However, drivers state that in many cases, the operation possibility on the steering wheel is not being used either due to the preferred conventional use of the middle console or due to lack of knowledge about the operation method.

The functions that are controlled on the middle console are usually associated with tertiary tasks such as the infotainment system, the radio and audio controls and the climate system. The operation on the middle console is implemented in most cars with a limited number of input elements with a focus on a multifunctional controller (MMI, iDrive, Command) and a display as output element. Lansdown et al. [6] assessed visual tasks as the biggest cause for an increased mental workload. According to Sacher, a third of all operations of the secondary and tertiary tasks is the interaction with the infotainment system, especially the multifunction controller. The most used features of the infotainment system are the navigation system and the radio menu. As the infotainment system has many combined systems in subcategories, various turns and pushes of the controller are necessary to access and adjust the desired functions. Operating the controller input while observing the display output for feedback has a high distraction potential on the driver.

Besides the operations in the vehicle in a moving state, Sacher has also explored the driver behaviour while the car is standing at the beginning and the end of a journey. Contrary to the interview statements, secondary and tertiary functions like adjusting the rear-view mirrors, the steering wheel and the seat are not always operated before starting the drive. These standard operations are only reliably executed when another driver has used the vehicle beforehand. If the driver believes no other user has been in the vehicle, adjustments of the mirrors are neglected completely. Adjustment of the seat is done gradually during the journey.

To conclude with the assessment of the user behaviour, we summarize that the focal points of our study will concentrate on less experienced drivers that are not knowledgeable with the entirety of the in-car user interface. We take from Sacher's dissertation [4] the fact that most drivers do not consult the user manual except when a problem arises and the driver is ignorant on how to solve it. Stated by Sacher's experiment, the most common feedback was that reading the manual is uninteresting and lacking a sense of gamefulness. We will determine the general attitude towards consultation of manuals in the following section and later derive with methods to increase user motivation to familiarize with given functionality before the use of a vehicle.

2.2. Usability Issues of Documentation

In Novick's and Ward's "Why Don't People Read the Manual" [7], they compiled an analysis of people's behaviour in problem solving when facing technical issues. They followed the hypothesis

that most users face usability problems with documentation on technical equipment and software nowadays which causes a level of frustration. They base their hypothesis on prior studies, conducted by Bessiere et al. [8] and Ceaparu et al. [9] which laid the foundation for their study. In these prior experiments, college students were asked to work on the computer with a natural behaviour that represents their day-to-day routine when facing technical difficulties.

Based on the results that state the level of frustration encountered by users in a digital environment, Novick and Ward conduct an in-depth interview with 25 participants that should determine a detailed explanation on how this frustration arrives and how people behave to solve a technical problem. In their results, they could not verify that the mean level of frustration is correlating with the mean level of self-assessed proficiency of the users. This means that users are not necessarily less frustrated with a system they are more proficient in, because frustration arises in situations when users encounter issues that require elements of the system that are not regularly used.

They further assess which problem solving techniques are applied in such situations. Their results confirm the hypothesis of prior studies that users tend not to consult printed manuals. The answers given by the participants stated that the main problem with manuals is that they are physically hard to handle, the navigation in the document is confusing and it is difficult to find solutions, and that if the issue can be found in the documentation, the answer is either too basic or too difficult to understand. Furthermore, printed manuals are seen as outdated and 'unstylish' by users. Although the results concentrate on software applications, we can see similarities to the automotive domain. Digital applications tend to avoid printed manuals in exchange for online manuals more recently, but for vehicles, the printed manual remains more common.

Input on Documentation Usability Improvements

Further results of Novick's and Ward's study state that users have difficulties finding functionalities because of intrinsic limitations of the graphic user interface. It is difficult for them to solve tasks if the functionality is not visible. This correlates with Kern's research about the rising number of functionalities in vehicles and their shared input elements [3]. Another problem the participants of Novick's and Ward's study refer to is that terms and keywords used in the documentation tend not to match with the user's vocabulary. Not being able to grasp the technical aspects in a manual also creates frustration on the user.

Novick and Ward propose elements necessary to an attractive solution of documentation in their related work "What Users Say They Want in Documentation" [10]. They see following points necessary to focus on when creating documentation that appeals to the user:

- navigation
- appropriateness of explanation

- problem-oriented organisation
- presentation
- completeness and correctness

The participants state that when searching for something specific, it is difficult to 'search correctly', if the user is not aware of the correct term or keyword. Including a broader set of synonyms would help with this problem, especially for novice users who are not familiar with the specific terminology. Furthermore, being able to browse through an index or a table of contents is helpful. Another suggestion is to prioritise items that are used more frequently so they are easier to find. The issue of the explanation not being appropriate is assessed by the participants due to the fact that all users are being perceived to be on the same level of knowledge which is the reason that some users find information too basic while it is too high-level for others. As most users tend to consult documentation when they face a problem, the users wish to have a list of known error symptoms combined with step-by-step instructions for the solution, a trouble-shooting section and examples. It is also stated that documentation often seems to be valuable for the initial use of a product, but can not provide necessary help on problems that occur later. On the presentation, it is stated that the help should be easily accessible, convenient, readily available and the information that is needed should be easy to find. A visual explanation such as screen shots and pictures is preferred to textual explanation. The document itself should be presented in a small and concise manner instead of being bulky and wordy. In addition to the documentation available, the participants state that additional sources of information should be given, such as web sites or numbers for human assistance. A general aversion against e-mail support is stated as the problem solving with this method is too slow.

2.3. Theory of Human Motivation

After raising the topic of usability problems with documentation, we will next analyse the issue from the user's perspective. We have covered that informative documentation is often not attractive to users. Reading manuals is not appealing which supports our hypothesis that users are not fully aware of the entirety of the functionality in vehicles. Next to raising the level of attractiveness of the documentation, we also want to analyse how human motivation is defined to assimilate new information.

In their paper, Ryan and Deci analyse intrinsic and extrinsic motivation and the connection and transformation between the forms. Motivation is defined as the factor that "moves people to do something" [11]. It is usually graded in the level of motivation which ranges from very little motivation to act to a great deal of it. Also, theories respect the orientation of motivation which concerns the underlying attitudes and goals that give rise to action. We have seen from

both software as well as automotive usability and behavioural studies that the level of motivation to familiarise with the functionality through documentation can be considered low. As for the orientation of motivation, users usually consult the manual in case of problems. The goal for the action would thus be problem-solving, a task that is executed in a frustrating situation. The arising attitude from the orientation of motivation is thus a negative one towards the acceptance of new information.

Intrinsic Motivation

In Self-Determination Theory (SDT, [12]), Deci et al. have categorised the types of motivation into intrinsic and extrinsic motivation. Intrinsic motivation is described as an interior force that drives people to act. Intrinsic motivation is higher valued as it is defined by actions that are inherently interesting or enjoyable and would thus result in high-quality learning and creativity. It arises from an innate psychological need for competence, autonomy, and relatedness. Competence describes the ability to understand and master goals through a relevant set of skills, while autonomy represents the possibility for a person to act on their own choice and avoid dependency from others. The relatedness is a factor that describes a person being connected to a family, a peer group, or a society. It results in a need for belonging and respect. Actions performed from intrinsic motivation are considered to be from free choices of a person and therefore associated with positive experiences. For our hypothesis, we suggest that automotive users belong to the category of established adult beings. They will thus value a high level of competence and autonomy. The goal of our application is to motivate the automotive user to willingly choose to familiarise with the vehicle's user interface. The intrinsic motivation of automotive users for this task is diminished though. Ryan and Deci state that threats, deadlines, directives, and competitive pressure undermine intrinsic motivation. We have established before that automotive users name a lack of time and interest responsible for the lack of motivation for learning about the vehicle's functionality. The definition given by Deci et al. for diminishing factors show that time and physical pressure are responsible for the lack of intrinsic motivation which correlates with our hypothesis. The free choice and positive reinforcement also lack as consulting documentation is predominantly used in situations where problems occur.

Extrinsic Motivation

Extrinsic motivation is defined as the underlying force for actions that lead to a separable outcome and can reflect exterior control. It arises from assuming responsibility for non intrinsically interesting tasks because of increasing social demands. Examples for extrinsic motivation are forcing a child to do their homework, but later also responsibilities in career and social life that require a person to act either to avoid sanctions or to gain rewards. Extrinsic motivation is thus seen as

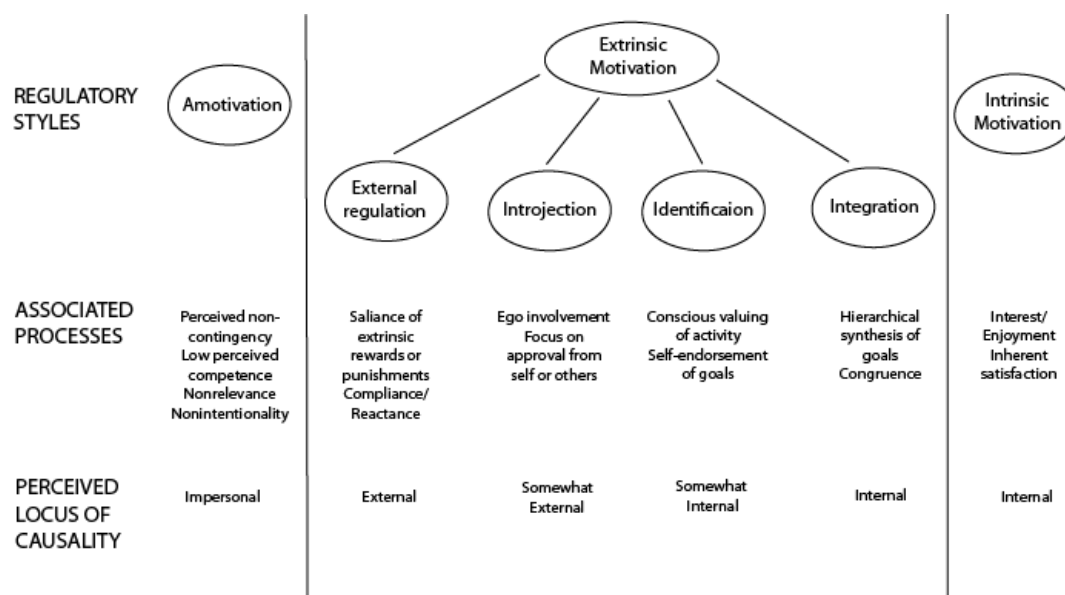


Figure 2.1.: Taxonomy of Human Motivation [12]

pale and impoverished in classic literature [13]. Even with a powerful reward, extrinsic motivation is perceived to be less effective than intrinsic motivation as it diminishes a person's autonomy and thus diminishes interest in following up on actions performed from extrinsic motivation. We can connect this theory to our case as consultation of documentation is only done in situations where a separable outcome such as problem solving can be perceived. In this case, the user is urged to perform the action and is giving up autonomy over the decision to learn. In a normal case, we can thus consider that the learning process is based on extrinsic motivation and not creating a lasting learning effect.

Organismic Integration Theory

In classic literature, external motivation is seen inferior to internal motivation for the reasons that it is not as long lasting [13]. The worst case is however, amotivation, the complete lack of motivation. Deci and Ryan also mention a subtheory of the SDT, the Organismic Integration Theory (OIT). In the OIT, the levels of motivation are connected to each other and it is presumed possible to elevate to more intrinsic levels of motivation. It also accounts for different types of users, not necessarily placing them in the same class from the beginning. On the far left of the OIT taxonomy is amotivation (Figure 2.1), the lack of intention to act due to not valuing the act, feeling incompetent, or not seeing a desirable outcome. In our hypothesis, we have established that the user is not compelled to learn and explore the automotive user interface. The user does not see the action as attractive and also doubts a desirable outcome when compared to the time invested to read a manual. Next to amotivation stands extrinsic motivation. Deci and Ryan

differentiate the extrinsic motivation different subcategories:

1. External Regulation
2. Introjection
3. Identification
4. Integration

External regulation is most external form of extrinsic motivation. It describes a state where actions are performed to satisfy an external demand or obtain a connected reward to the task. This is the form of extrinsic motivation that is classically contrasted with intrinsic motivation. It is an initial point to induce motivation into an amotivated person. By creating a tangible compensation for an action, people are attracted to act. Step 2 in extrinsic motivation is introjection. In this state, actions are still quite externally controlled, but the person has a certain level of self-determination to act. The wish to act in this state is out of feeling pressure in order to avoid guilt or anxiety or to attain ego-enhancement or pride. It is connected to an ego involved form of relatedness where the person needs to justify their value in their peer or society group and wishes to enhance their self-esteem. Step 3 is the identification, which is considered to be somewhat more autonomous. This state is achieved when the user can relate to the actions and has identified with the personal importance of the behaviour. The most autonomous form of extrinsic motivation is the integrated regulation. In this form, a person has fully assimilated regulations to their self. The user is fully self-determined to perform an action and is not driven by external control. However, the behaviour is still seen as a means to an end with external gratification which is why it is set in the group of extrinsic motivation. For the intrinsic motivation, the driving force for the behaviour is merely interest, enjoyment or satisfaction. External factors such as rewards, validation or general tangible outcome are not important for the actions performed.

2.4. Gamification - A Practical Means for Creating Motivation

In the previous section, we have laid out the theory of how human motivation is defined in theory. We have seen the different forms of motivation and follow the thesis that an amotivated person can reach a high level of motivation throughout a course of different levels of extrinsic factors. The factors range from external gratification and the need of belongingness towards identifying and integrating externally posed behaviour to the personal goal. To a certain extent, Gamification is trying to connect with a user in this form and eventually achieving the transition to more intrinsic actions and behaviour from a user.

As Gamification is a relatively new concept, no fixed definition has been set for it. Deterding et al. describe in their work [14] that the term fluctuates between two related concepts though.

The first is the increasing adoption, institutionalisation and ubiquity of games and video games in everyday life. The second concept is that it is a use of game elements in non-game products and services to make them more engaging and enjoyable. Gamification is also seen as a strong market concept in various sources, however, we decide to concentrate on the educational and engaging purpose of Gamification in our work and will leave out researches that concentrate on the financial advantages.

Deterding et al. state that the term "Gamification" originated from the digital media industry in 2008. The idea itself is not entirely new though, as ideas for designing more enjoyable user interfaces arose in the 1980s and games with a serious purpose were applied in military before migrating into education and business in the second half of the 20th century. The movement to increase the utilisation of Gamification sets its goal to piggyback game play with in a non-gaming environment to increase the playfulness, and the desirability of the experience or user interaction. Sacher's research determined a lack of playfulness [4] as one of the reasons why people were not motivated to increase familiarity with the automotive user interface.

Towards a Definition

Deterding et al. continue with an approach towards a definition of Gamification. They relate gamification to "games", not "play" as is described in Caillois et al.'s concept of *paidia* and *ludus*[15]. *Paidia* describes the playing aspect of a game that is characterised by a more free-form, expressive, improvisational and even chaotic behaviour. *Ludus*, the gaming aspect, captures the structure of playing that is defined by rules and competitive strife towards goals. Gamification should capture the essence of *ludus* and therefore it is proposed that gameful design concentrates on the gamefulness rather than on the playfulness. To achieve gamefulness, Deterding et al. propose to take game elements and design into consideration.

Game Elements & Design

They consider Reeves' and Read's "Ten Ingredients of Great Games" [16]:

- self-representation with avatars
- three-dimensional environments
- narrative context
- feedback
- reputation, ranks and levels
- marketplaces and economies

- competition under rules that are explicit and enforced
- teams
- parallel communication systems that can be easily configured
- time pressure

Deterding et al. argue that each of the points can be found outside a game also, and in isolation, they cannot be specified as 'gameful' or game specific. They take into consideration another classic game model by Juul [17] that states that "a game is a rule-based formal system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome, and the consequences of the activity are optional and negotiable." This definition is also only valid for a game if taken as a whole set. The final proposal that Deterding et al. make for defining game elements is to define them as elements that are *characteristic* to a game. This definition includes elements that are common in games, but do not necessarily have to be present, which are associated with games, and play a significant role in game.

Next, Deterding et al. propose that Gamification does not include all necessary and sufficient conditions to be classified as a game but only utilises game design elements. They categorise these design elements into different levels of abstraction (seen in Table 2.1). The top level is the most concrete level, i.e. the elements that belong to this level are easiest recognisable. As the level in Table 2.1 gets lower, the proposed elements get more abstract and intangible. They change from concrete elements that can be perceived to underlying concepts that generate gamefulness.

Levels	Description	Example
<i>Game interface design patterns</i>	Common, successful interaction design components and design solutions for a known problem in a context, including prototypical implementations	Badge, leaderboard, level
<i>Game design patterns and mechanics</i>	Commonly reoccurring parts of the design of a game that concern gameplay	Time constraint, limited resources, turns
<i>Game design principles and heuristics</i>	Evaluative guidelines to approach a design problem or analyze a given design solution	Enduring play, clear goals, variety of game styles
<i>Game models</i>	Conceptual models of the components of games or game experience	MDA; challenge, fantasy, curiosity; game design atoms; CEGE
<i>Game design methods</i>	Game design-specific practices and processes	Playtesting, playcentric design, value conscious game design

Table 2.1.: Levels of Game Design Elements [14]

Non-Game Context

The predominant purpose of Gamification is enhancing the joy of use, engagement, and generally, the user experience of applications that are not primarily for entertainment by utilising elements of games that are usually connected to entertainment games. Deterding et al. argue though that the context of Gamification should not be strictly limited to entertainment purposes, as they see advantages of Gamification wider spread. The raising of attractiveness of applications can be helpful for areas such as health, training, or social conscience. Very good examples for gamified applications that *RecycleBank*¹ and *FoldIt*². *RecycleBank* encourages people to take everyday green actions by rewarding them with discounts and deals from various local and national businesses. We have established with Ryan's and Deci's OIT that amotivated people can be given an incentive to act by external rewards. In general, ecological behaviour is unattractive to people as it requires extra effort. Thanks to a small financial gratification in form of discounts, an initial push is given towards the behavioural change. The system works on initially changing

¹Recycle Rewards Inc., RecycleBank, <https://www.recyclebank.com/>

²University of Washington, FoldIt, <http://fold.it/portal/>

a person's mentality to gradually have them identify and integrate with the change in behaviour and eventually keep the change without incentive.

FoldIt is one of the most exceptional examples for the success of Gamification. It was developed in collaboration by the University of Washington's Center of Game Science and their Department of Biochemistry and presents the user with a quiz-game like interface. The task is to fold protein structures in the most optimal way. Although it is a scientific tool, through Gamification, non-scholastic users have the opportunity to explore levels ranging from simple structures to very scientific and advanced ones. A score is determined, based on how well folded a protein is, users can connect to groups and share accomplishments and high scores. The amazing accomplishment of *FoldIt* is that within a short time of the application being published, the community has unlocked the structure of an AIDS-related enzyme that the scientific community has not been able to unlock so far³. Through gamifying scientific research, *FoldIt* has accomplished to incorporate entertainment to a non-gaming application which is leading towards scientific advancements in health care. It stands as a strong advocate for the statement given by Deterding et al. that Gamification can achieve a wider reach.

Gameful Design for Educational Achievement

It is not surprising that a game-like application finds the level of success as it did with *FoldIt*. The application represents research in a format that the modern generation is highly familiar with. Prensky describes this modern generation as the first of "digital natives" [18]. Students nowadays are the first to completely be surrounded by and using computers, video games, digital music players, video cams, cell phones and other gadgets of the digital age for a dominant part of their lives. He proposes that the way digital natives think and process information is fundamentally different than the predecessor generation. The information processing applies faster – not necessarily more thorough – for them, multi-tasking and parallel processing is common and graphical stimuli are preferred to textual. The familiarity with video games as well as the preference for graphical stimuli are reasons why this puzzle-gamified application has led to a scientific breakthrough and are also the reason why Prensky proposes that the form of education needs to change drastically to adopt to the digital generation, e.g. through mobile applications [19].

Lee et al. explore the possibilities of using gameful design elements for educational purposes [20]. They acknowledge that for digital natives, learning through traditional methods is unattractive, as the lack of motivation derives from an insufficient emotional engagement. Similar to the identification and integration of the OIT, the emotional connection with a goal is a necessary factor for perceiving information and learning. Lee et al. see that it is more likely to create emotional bonds with (video) games and thus propose using game mechanics for education.

³M. Peckham, "Foldit Gamers Solve AIDS Puzzle That Baffled Scientists for a Decade", <http://goo.gl/owUH6V>

They differentiate between Gamification as an attempt to extend game thinking to a non-game context paired with rewards as extrinsic motivation and gameful design which focuses on intrinsic motivation.

To stimulate intrinsic motivation, Lee et al. propose using game mechanics in the design to provide value to the user with which they can relate in real life. The important traits to a game that they incorporate are:

- goal
- rules
- feedback system
- voluntary participation

To have a clear defined goal and a bounding set of rules correlates with Deterding's definition of 'gamefulness' as opposite to mere 'playfulness'. The feedback system is a common game element that is represented by a scoring system to give the user feedback on the performance. A voluntary participation will more likely create intrinsic motivation without having to externally motivate users first. Lee et al. further suggest implementation of an avatar with which the user can relate [20]. Role-playing games have shown that users strongly connect to their digital character to a point where they invest time and emotion for it. An avatar targets the same emotional response from users and thus users can connect with a real life value when improving the avatar. Another game mechanic is the progress bar that provides a visual feedback which motivates the user with how much they have accomplished so far, challenges with remaining unsolved content, and helps keep track. As the learning progress is intangible, Lee et al. propose that the visual game mechanics are an important factor to help the user connect better with the application and create an emotional identification for them self.

Concepts for Meaningful Gamification

Nicholson argues that it is not enough just to utilise game elements on a shallow level [21]. A criticism on Gamification is the primary use of scoring and reward systems which the game community sees as the most trivial and boring part of a game. Furthermore, external incentives such as rewards can diminish or replace intrinsic motivation with extrinsic motivation. Due to this reason, Nicholson proposes that game-based elements need to be meaningful and rewarding on their own without relying on external rewards. He suggests in connection with the OIT that rewards exert a heavy external control and aspects of this external control will be integrated instead of a self-regulation by the user. Autonomous, internalised behaviour is much more likely to arise if the user can identify with a group or a goal that are meaningful to themselves.

The concept of "situational relevance" states that predetermined goals by an outside source will only be effective with a user if they are relevant to the user's background, interests, or needs. In Human-Computer Interaction (HCI), the related "situated motivational affordance" states that the aspects of a system need to match the aspects of the user's background to motivate them. These two concepts lead to the result that a meaningful gamified system needs to encompass backgrounds, interests, and needs of a variety of users.

The first strategy Nicholson presents is to create meaningful Gamification by considering following points:

- different ways to present the content of learning - the "what"
- different activities for the learner to explore and demonstrate mastery of content - the "how"
- different paths to internalize content and become engaged and motivated - the "why"

For the "what", the designer needs to analyse the underlying aspects of the non-game activity that are being 'gamified' and consider different ways to reach the desired outcomes of the non-game activity. The "how" should allow the user to select the methods in the gamification system that are most meaningful to them without having to stick to a certain achievement system. The "why" represents the possibility for the user to explore the system in different ways to find the game elements that are most meaningful to them.

Another popular game design feature is player-generated content. With increasing online connectivity, games have given the user the opportunity to create their own environments within the game. A practical solution that is presented to implement this feature in a gamification context is to allow the user to set their own goals. The gamification system needs to adapt to this possibility and put constraints on the user's choices to guide them to a desired learning outcome while leaving them the freedom to connect to the goal in a way that is meaningful to them. The system should be transparent about the constraint process for the user to understand why restrictions are in place and which game elements are connected to the learning outcome. Ideally, the gamification system shall provide the user the opportunity to create their own levelling system and achievements, develop their own methods of engaging with the activity and be able to share the contents with others. The sharing of content can evolve towards a community of users that have the same individualised learning goals and will likely lead to a stronger internalised experience.

Both these proposals by Nicholson put the user in the centre of the gamification system. He suggests that "*Meaningful gamification is the integration of user-centred game design elements into non-game contexts*". The main question to the designer has to be "how does it benefit the user" instead of using external rewards to control behaviour which can lead to negative feelings about the underlying content of the system. Another design to avoid is 'organisation-centred' which puts the needs of the organisation above the benefits for the user. In the same sense, Nicholson rejects 'mechanic-centred' design that implements new or interesting game mechanisms

that do not integrate with the non-game content. Nicholson's proposal is to dismiss shallow use of game design elements and focus on the user's needs to create meaningful gamification.

2.5. Criticism on Gamification

We have established before that external rewards can be a threatening factor to successful and meaningful gamification as it can diminish intrinsic motivation or completely replace it with extrinsic motivation. According to Jiang, it also diminishes creativity [22]. She picks up on Priebatsch's work that compares schools to near-perfect game ecosystems [23]. Priebatsch explains that all necessary elements of a game system are present in the school surroundings with the students being the players, the tests being challenges, the grades being rewards, classes representing appointment dynamics and further existing game mechanics. Priebatsch's proposal is that the lack of engagement of students stems on a poorly designed grading system. A deeper level of gamification would eradicate the problem by exchanging grades for experience points (XP), where students cannot drop levels, but a better accomplishment would lead to a bigger earning in XP and a faster rising in levels. Jiang however, states that the fundamental problem of a student's poor engagement is from weak intrinsic motivation. Experience points as reward is an addictive game mechanic and thus utilised in games where players level up quickly especially in the beginning. Jiang explains that offering a reward for a task is a signal that the task by itself is undesirable. She sees the two possible consequences from incited engagement as either: 1) that the task will never be performed without the external reward or 2) that when the initial enthusiasm from the reward dissipates, the benefits from the reward have to increase to keep the player interested.

An additional drawback from external rewards that has been perceived is that they can also decrease creativity. In 1973, Lepper, Greene, and Nisbett conducted a study on motivation where the participating children were asked to draw a picture. The results showed that the group that was promised a reward spent less time to finish and played less with the given drawing material compared to the group of children that was not expecting a reward. In an earlier study in the 1960s, Glucksberg conducted a study on the creativity and cognitive performance test "candle problem" (Figure 2.2). The participants were given a box of tacks, a candle and matches and got the task to fix the candle to the wall without wax dripping on the table. Glucksberg divided the participants in two groups. One group was given no reward, the other group was promised an amount of money that is comparable to 39 \$ nowadays for the fastest 25 %, and a reward value that is comparable to around 150 \$ for the fastest. The result showed that the incited group took 3.5 minutes longer on average than the control group.

A final problem that Jiang mentions is cheating. Especially when financial rewards are in place, players will try to find loopholes in the system to take an unfair advantage. Jiang gives an example from Red Gate Software, where salespeople received an extra commission for number of sales and



Figure 2.2.: The Candle Problem

increase in sales over the previous month. After figuring out the reward algorithm, the salespeople would purposely reduce their sales in certain months to exploit the system for the highest reward possible. After eliminating the reward system and paying the salespeople a fair fixed salary, the overall sales would increase.

We can conclude that rewards are a powerful mechanic when it comes to games and gamification. In the OIT, external incentives can give an initial push to an amotivated person to be extrinsically motivated and slowly identify with and integrate a behavioural change. However, if the external regulation is the pressing factor for a person to use a system, the reward will be more important than the underlying context of the system. The user can eventually be more interested in the reward than in making the emotional connection to the context of the system. Further disadvantages of this outcome can be a decrease of creative use of the system, explore other elements than those connected to the reward, and exploiting loopholes in the system to gain the best possible reward. In this case, for an educational system, the user will not realise the underlying purpose of the gamified system.

As seen in Table 2.1 in Section 2.4, the most concrete game design elements for a gamification system are levels, leaderboards, and badges. This means that they are also the most common elements to encounter when dealing with gamification systems. A mistake with the use of badges is not creating a value for them⁴. The badge system has found its popularity with location-based systems like *Foursquare*⁵ and *Foodspotting*⁶ where users get badges for checking into specific venues or completing certain tasks. Various other systems have since started implementing badges, such as the online vendor *Zappos* who rewards premium users with badges for tasks like signing

⁴A. Kleinberg, "Brands that failed with Gamification", <http://goo.gl/M6P3aC>

⁵Foursquare Labs Inc., "Foursquare", <https://foursquare.com/>

⁶Foodspotting Inc., "Foodspotting", <http://www.foodspotting.com/>



Figure 2.3.: Example of Zappos Badges

up for brand notifications or writing product reviews⁷. The collected badges translate to a reward that allows the user free shipment of products. *Zappos'* badge system (Figure 2.3) tries to attract the user with external incentives and the tasks for receiving badges show an organisation-centred design that urges the user to perform actions that benefit the company itself and not have the user connect with the underlying context.

Another criticism that Gamification faces from the game community is that the terminology is fundamentally wrong as Gamification does not capture the essence of a game but only takes the weakest and most shallow element of a game, the scoring system. A strong advocate for this opinion is Bogost who recommends replacing the term "gamification" with "exploitationware"⁸. He states that only few "serious games" which describe game-like systems with an underlying non-game character, have been implemented well to both capture the essence of gaming and serve the serious purpose. According to Bogost, it is the reason why the term "Gamification" was coined. The game is still included in the terminology, however through the "-ification" suffix, a system is adapted with a particular state, or quality. Bogost especially criticises Zichermann's statement that "*points, badges, levels, challenges, leaderboards, rewards, and onboarding*" are key game mechanics⁹. According to Bogost, points and levels are mere gestures that provide structure and measure progress in a system, whereas key game mechanics are the operational parts of the game that can induce a variety of sensations to the user ranging from interest, enlightenment, terror to fascination, or hope. Bogost cites Robertson's term "pointsification"¹⁰ as a fitting explanation for the strategy of taking points, levels and badges as the least essential aspects of games and transforming them to appear as the most essential.

Although Bogost's criticism is of a harsh nature, we can see in Table 2.1 in Section 2.4 that also Deterding has perceived a different notion of game design elements than those regularly used and sold as gamification. As we go further down in the table, the design elements get more intangible, but always remain valid characteristics of good games. It is important not just to include game design interface patterns, but also to conceptualise a model first. Badges, leaderboards and levels are useful as visual feedback for the user to realise the possibilities of the gamification system,

⁷Zappos' Globe Rewards System, <http://vip.zappos.com/d2/vip-globes>

⁸I. Bogost, "Exploitationware", <http://goo.gl/jK1VR>

⁹G. Zichermann, "The Purpose of Gamification", goo.gl/Y91FKb

¹⁰M. Robertson, "Can't Play, Won't Play", <http://hideandseek.net/2010/10/06/cant-play-wont-play/>

however should not be in the focus or the only existing game elements.

2.6. Evaluation of Existing Gamification

We have established the motivational aspect of a system so far and taken as a basis which factors are likely to generate emotional connections between the user and a system. We have shown that rewards can be used as an initiator to get a person motivated, but that it can also endanger further intrinsic motivation of the person to connect to the system. We have further classified how Gamification is defined at this point in research and the game design elements it should contain to both be effective as well as meaningful. Next, we will take a look at both successful and failed gamified platforms and applications and assess where they correlate with the theory and what to avoid.

FoldIt

We have mentioned *FoldIt*¹¹ as one of the best examples for meaningful and successful gamification before. Now we want to examine the game mechanics to find out which elements it implements. The underlying context of the game is scientific research of optimising protein structures which is normally done by computers. As computers follow algorithms to optimise the structure, they can get stuck. *FoldIt* transfers this task to manual human input and is therefore a trial-and-error method for solving complex scientific problems. This strategy can be compared to outsourcing computational resources to a multitude of research assistants and also bringing in a creative factor that computers lack. The user interface (Figure 2.4) has multiple viewing options from very basic ones to complex, scientific modes so user of each experience level can pick the most fitting. A tutorial mode teaches the user the available tools step by step and the biochemical components are broken down to graphical elements with which the user can familiarise. Next to the tutorial mode is the challenge mode that allows the user to compete against others in solving puzzles that are actually existent in real life. The score which the user receives is based on how optimal the protein has been folded. This means that the user does not have to have knowledge of the underlying biochemistry itself, but has a visual feedback how well the task is accomplished. As the score is also used for a leaderboard, the user can always keep track if there are more optimisations possible so it plays on the curiosity and a certain level of ego-enhancement of the user to create motivation to try again. The community is formed by an in-game chat and groups so people with similar interests can help and educate each other.

Due to the nature of the underlying non-game context, *FoldIt* manages to motivate players on an identification level from the beginning as healthcare is an issue that most people can relate with. It

¹¹University of Washington, "FoldIt", <http://fold.it/portal/>

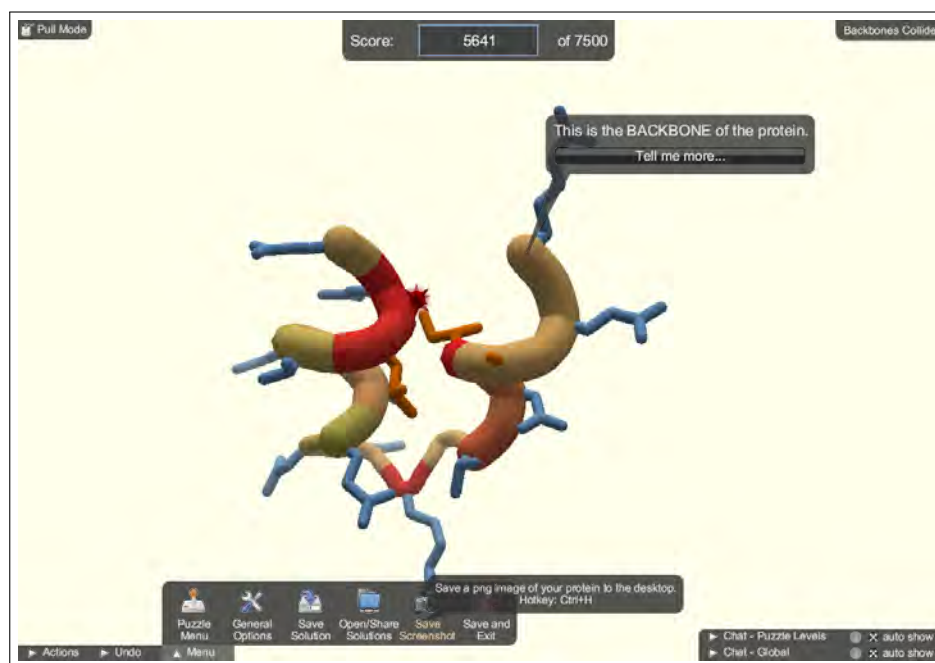


Figure 2.4.: Example of FoldIt User Interface. Gamified Tool to Tackle Optimal Protein Folding.

has a strong potential to reach the intrinsic motivation as there are no rewards, but the user plays it for the mere enjoyment. With the scoring system, it always keeps an ego involvement of the user active, but the approval and recognition for a user are not shown in tangible gratification but recognition from the community. The game interface design patterns include points and levels that are apparent in the interface but do not play a major role above their importance. The goals of the game are clearly stated, the options available to the user described comprehensibly which satisfies the specifications of game design heuristics and principles. The game model is well thought through and implemented as the challenges leave room for curiosity and creativity of the user to continue exploring the tasks. In total, *FoldIt* satisfies both concrete and more abstract levels of game design elements that are given in the theory of Gamification.

EpicWin

Another example for Gamification is *EpicWin*¹² which is a to-do list application. Similar to other mobile to-do list applications like *Astrid*¹³ or *Remember the Milk*¹⁴, *EpicWin*'s underlying non-game context is an organisation and efficiency tool for individuals that manages tasks monitoring and execution. *EpicWin*'s user interface is built up similar to a role-playing game (RPG) in contrast to other to-do list managers. The user can choose between different avatars that they

¹²Epic Win To-Do List Manager, <http://www.rexbox.co.uk/epicwin/>

¹³Astrid To-Do List Manager, <http://astrid.com/>

¹⁴Remember the Milk To-Do List Manager, <http://www.rememberthemilk.com/>



Figure 2.5.: Example of EpicWin User Interface. To-Do List Manager with RPG Elements.

feel represents them best and can set their own tasks. The avatar possesses different attributes such as stamina, health, or intellect, and the user can assign the amount of XP won for certain attributes while setting the tasks. Upon completion of the tasks, the user's avatar is rewarded with the XP which levels the avatar and fills up a progress bar that is represented by a road map of a virtual quest. On different locations of the road map, the user has the possibility to attain unknown loot items that represent badges.

RPGs like *World of Warcraft*¹⁵ or the *Final Fantasy*¹⁶ franchise have shown huge success in the video game industry as they manage to capture their consumers in creative, fantasy worlds and well-written story-lines. Players can relate to the protagonist's story and the engagement in playing is formed from an emotional bond between the player and the game character. *EpicWin* emulates the connection to a virtual avatar that represents the user and tries to transform mundane tasks to part of an adventure. The game model correlates strongly with Nicholson's work on "situational relevance" as established in Section 2.4. The application gives the user a framework to set up their own tasks and imagine their own quest without binding them to pre-set goals. The application fulfils the criteria for different activities to achieve mastery and different paths to internalise the content and become engaged and motivated which makes the context of the application meaningful to the user. The application also meets with Deterding's proposal for game design elements with a capturing game interface design, and given game design mechanics such as time constraints. The heuristics are met by clear goals which the user can specify themselves, the interaction with the

¹⁵M. Zenke, "Why World of Warcraft Made it Big", <http://goo.gl/FuH1H8>

¹⁶T. Ciolek, "The Secrets of Final Fantasy VII's Success", <http://goo.gl/EymPt8>

application involves the challenge to complete self-given tasks to advance, and fantasy elements. *EpicWin* leaves the user room to incorporate their own creativity as they can imagine their own quests, and cleaning the toilet can become defeating the sewer monster to rescue a princess.

Although *EpicWin* includes well-designed game elements and leaves the user room to establish their own relevance with the non-game context, it faces the issue that the scoring system is a very dominant part of the application. Jiang has stated that offering reward implies that the task by itself is unattractive which certainly applies to tasks that are covered in to-do lists. The results she proposed were that without the reward, the user would either not feel compelled to complete the task or that at some point, the given reward is not sufficient any more. Levelling up a hero starts feeling repetitive and boring after a while if no apparent improvement can be seen and with *EpicWin's* avatar, the attributes and level represent a mere feedback without further development in the game. The user will eventually be either focused on levelling the hero to the maximum as fast as possible and spend less time and diligence on the task or find loopholes to achieve the final goal without actually focusing on the underlying non-game context any more. In these cases, no lasting intrinsic motivation can be achieved due to the fact that the strong scoring character of the application eclipses the non-game context.

Real-Life Gamification

Gamification is not necessarily limited to the digital world as examples of gamified environments have shown. A good example is Volkswagen's initiative *The Fun Theory*¹⁷ with the slogan "Fun can obviously change our behaviour for the better." Volkswagen initiated a competition in 2009 for people to come up with ideas that can be implemented in the real life environment and change people's behaviour by making unattractive tasks fun. One of the noticeable examples of the initiative is the "piano staircase"¹⁸ (Figure 2.6) which is a modified staircase in a public environment. The staircase is next to an escalator and in general, it can be observed that more people tend to use the escalator than the staircase. The staircase is modified with pressure sensors and auditory feedback so that each step resembles a key of a piano. The result that can be observed is that more people start using the staircase to activate the sound. The concept plays on the curiosity and playfulness of people and attracts them to try out the functionality. The inventors of the piano staircase state to have recorded that during the trial of the concept, 66 % more people used the staircase compared to before. The goal is to sensitise people to using stairs instead of an escalator, however, from this singular experiment it is not traceable if lasting integration of the non-game context can be made and if a sustainable change in behaviour occurs¹⁹.

¹⁷Volkswagen, The Fun Theory, <http://www.thefuntheory.com/>

¹⁸Volkswagen, Piano Staircase, <http://www.thefuntheory.com/piano-staircase>

¹⁹Pelle, "The Piano Stairs of Fun Theory – Short Run Fun and not a Nudge!", <http://goo.gl/wr1z2q>



Figure 2.6.: Piano Staircase Playing Music when Stepped Upon. Concept Developed to Sensitise People into Using Stairs instead of Escalator.

A similar project has recently been implemented in Russia as a promotion for the 2014 Sochi Winter Olympics²⁰. A ticket booth in a Russian subway station has been modified with a camera to detect people doing squats and reward participants a free ticket for doing 30 squats. The underlying context of the activity is to connect with the athletic value of the Olympic games and motivate people into exercising. The reward is small enough not to get into the main focus of the system and as only one booth is fitted with the modifications, cheating is less likely to occur to exploit the system of additional rewards. The motivational factor for participating are again a sense of curiosity and fun, as well as a sense of challenge. Similar to the piano staircase, as it is a singular task, sustainable behavioural changes are not traceable.

Accident Bucket

We want to take a closer look on what seems to be a rather controversial Gamification idea proposed by Law et al. in their paper "Gamification towards Sustainable Mobile Application" [24]. Lee et al. start their analysis of Gamification by referring to game mechanics that are represented by points, levels, and challenges as well as game dynamics which include reward, status, and achievement. From a mobile application design view point, they take into account Gualtieri's five (5) dimensions of the mobile context: location, locomotion, immediacy, intimacy, and device [25]. According to Gualtieri, a mobile application needs to be accessible from any location, allow use of the application while the user is performing other tasks, be available when the user needs it, allow the user the use of the application for different purposes, and utilise the capabilities of the mobile device.

²⁰ J. Catcher, "Russian Subways Now Accept Squats for Payment", <http://goo.gl/it7Kn8>

Lee et al. present their concept for a gamified mobile application called *Accident Bucket* which is categorised as utility and tool. The application's underlying non-game context is the support of reporting traffic accidents through exact GPS location of the mobile device. Users are encouraged to take the virtual character of a reporter, traffic controller, or citizen within the application. The reporter's task is to send pictures of accidents with the GPS location for verification of an accident. Traffic controllers should find suitable alternative routes to bypass traffic jams caused by the accident. The citizens' task is to rate or give recognition to well documented work done by the reporters and traffic controllers. The users get points and badges depending on their character's tasks as well as commenting and being active in the community.

Although it is most likely intended that the underlying non-game context is traffic safety, the implementation seems to be rather controversial. The goal is not to sensitise people into being more careful in traffic and preventing accidents, but to report accidents that have already happened. The application evokes curiosity in a critical way as it relies on rubbernecked pedestrians to take pictures of accidents. As points are rewarded for these pictures, a possible consequence of this behavioural encouragement could result in users interfering with the traffic to exploit the scoring system in a worst case scenario. The application itself limits Gamification to game interface design elements and game mechanics and puts the scoring system in the focus. Deeper levels of the game design elements are not being achieved.

Gamification in an Automotive Environment

Finally in this section, we want to give an overview of gamified systems and applications that are connected to the automotive environment [26]. Car manufacturers have started to implement display options that show the vehicle's statistics in a design that would resemble a game interface. The display is a visual feedback about the consumption and connected statistics and is supposed to capture the driver's awareness on it. Hybrid cars such as the Toyota Prius (Figure 2.7), KIA Optima Hybrid or the electric car Nissan Leaf combine these display information with an "eco-score". Depending on how ecologically the driving behaviour is, a score is calculated on the speed and fuel or energy consumption of the car. Nissan's Leaf shows this score as a number of trees for the entirety of ecological driving behaviour, KIA's Optima Hybrid shows the user the energy flow between the battery and the fuel engine in its "EcoDynamics" display and further settings for the Eco Level. With this design, car manufacturers take a step in the right direction to save resources and sensitise drivers to eco-friendly driving. We can assume that people who buy hybrid cars are ecologically sensitive at least to a certain degree, but according to Dorrer, the car's fuel consumption can vary up to 50% depending on the driving behaviour as most drivers are not aware how to drive efficiently [27].

Ecker et al. conducted a small explorative field study on the subject of visual feedback for

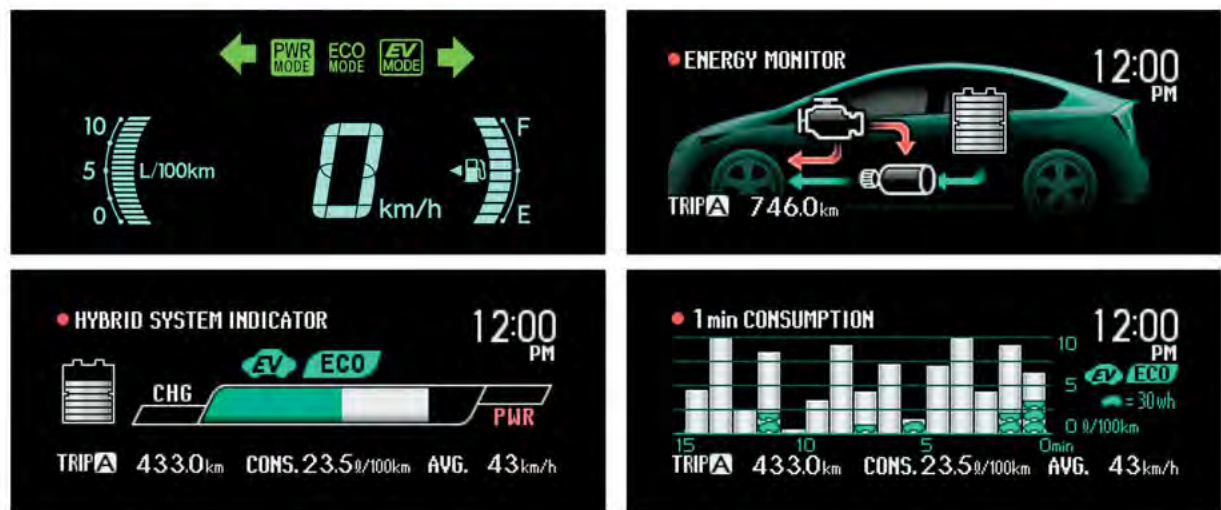


Figure 2.7.: Dashboard Display of the Toyota Prius. "Eco-Score" for higher Sensibility towards Eco-Friendly Driving.²¹

persuasive, efficient driving behaviour [28]. They implemented a prototype GUI that shows an amount of fuel that is given for a fixed distance as well as indicators on the best, average and worst score. The five (5) participants were asked to drive under base condition without the GUI first and later with the display on fuel consumption. The experiment consisted of two different challenges, the results showed a clear decrease of average consumption in one challenge (\varnothing 7.6 l/100km base, \varnothing 6.2 l/100km challenge), while the second challenge was more ambiguous (\varnothing 6.0 l/100km base, \varnothing 5.4 l/100km challenge). The results show that the implementation of visual feedback for fuel-efficient driving can have advantages, but the participants of the study stated that the additional display is distracting from the primary driving task. Deterding states in his presentation "Pawnd - Gamification and its Discontents" that the distraction can also lead to hazardous traffic behaviour [29]. Participants of an EcoChallenge engaged in unsafe driving practices, like dashing over red lights because stopping and restarting would use more fuel.

Volkswagen and Google developed the mobile application *SmileDrive*²² together, a location-based application that lets users record and share their driving statistics. *SmileDrive* is connected via Bluetooth to the car and records journey specific data like distance and weather. It has a social component that is called *SmileCast* which lets the user tag passengers and share pictures of the journey and the journey itself on social networking platforms. The user receives stickers for specific journeys like driving in the morning, driving in the evening, or passing by the same car model. *SmileDrive* operates in the background during the drive so it does not distract the driver. It does not possess a serious underlying non-game context as the developers state that the goal is to make the drive more enjoyable and collect memories. The application does not play on the user's motivation and does not try to create a behavioural change. Regarding the game design elements, it remains in the most concrete levels. Overall, *SmileDrive* can be seen as a nice-to-try application, but not as a strong implementation of mobile Gamification in the automotive environment.

²²Volkswagen and Google, *SmileDrive*, <http://smiledrive.vw.com/>

Chapter 3.

Concept of a Gamified Driver Assistance Mobile Application

In the previous chapter, we have covered an assessment of vehicle functionality and driver behaviour. The results of the assessment show us that drivers perform a high number of in-car operations during a journey which pose an additional mental workload on the driver. In addition to the unknown factor on the driving performance that secondary and tertiary task operations pose, it was established that these safety-impairing factors rise with sinking proficiency of the task operation. We have further established that in most cases, the driver's knowledge on the vehicle's functionality is limited and the motivation for consulting the documentation on the functionality is lacking. We have analysed the issues with the usability of documentation and the theory on human motivation. We have introduced Gamification as a practical means to encourage motivation from users and have given examples on existing Gamification models.

In this chapter, we will take the established theoretical information of the previous chapter and we will introduce a concept for a mobile driver assistance application [30] that will incorporate the principles of Gamification that we have found.

3.1. Android Design Principles

We have mentioned Gaultieri's five dimensions (Figure 3.1) of mobile content [25] during our coverage of *Accident Bucket* in Section 2.6 before. Although we deemed that the concept and execution of the application was rather controversial, Gaultieri's points still hold for the development of mobile applications. We will cover them more in detail and assess them for our design considerations.

Location

In recent years, the smartphone has obtained the ability to comply with many needs the user has. From finding information quickly through web browsing, getting in contact with other people, or even doing office work on the go, mobile applications give users the possibility to operate while staying mobile. Thanks to their versatility and small size, they are on par with desktop computers in terms of community, task management, and entertainment. This is why people rely on their mobile device and their software to be accessible from any location. Our mobile application is technically a driver assistance program [31], but users' expectations on it will go further than being confined to the car environment. For this reason, we will implement a function which users can access from any place.

Locomotion

The term locomotion means that users will also expect to use their mobile devices while on the move. Our application should also work while driving where we have to expect the user to be unable to use the full range of input gestures. A further consideration while driving is the additional mental workload from visual tasks on the driver as stated by Lansdown et al [6]. While our application is connected to the car, it must therefore cause as little visual distraction to the driver as possible and interactions must remain at a minimum.

Location	Mobile users can use their mobile device wherever they are.
Locomotion	Mobile users can use their mobile device on the go. Users may be walking, running, in a car, on a boat, or in any other manner of motion while using a mobile device.
Immediacy	Mobile users can use their mobile device at a moment's notice.
Intimacy	Mobile users may use multiple devices for different purposes, and a device's use can vary from a digital appendage to an occasionally used device for a specific personal or work task.
Device	<ul style="list-style-type: none"> • Mobile devices vary greatly in form factor and capabilities. • Smartphones, eReaders, tablets, and other devices.

Source: Forrester Research, Inc.

Figure 3.1.: The Five Dimensions of User Experience Context [25, p. 6]

Device

Smartphones are the Swiss knife of technology. They implement a high number of different input modalities such as gesture, touch, and voice recognition, and image recognition as well

as photo and video cameras and mobile music players. One of the difficult tasks of designing an application on Android devices is to include the factor that the devices have different screen sizes and resolution, different computing power and different capabilities of their elements such as resolution of the camera. These factors have to be accounted for when designing a mobile application.

Our application is supposed to run on both smartphones as well as tablets. We have to account for the lower computing power and lower memory of smartphone devices which is why the application should not take up too many resources. In our application, the most resources will be used by the graphical representation of the cockpit. Since the application has many graphical elements and their resolution should be high, we will try to prevent further unnecessary resource consumption in the background for smoother operation of the application. The resolution of the graphics will also have to account for different screen resolutions to run on different devices.

Besides taking the use on different devices into consideration, paying attention to the device means also to utilise the technical possibilities of the device to its maximum. A good example for the use of the camera is Audi's augmented reality mobile application that informs the user about the elements of the vehicle¹. Audi has realised the problem of static and outdated printed manuals that we have covered and has implemented a mobile application together with Metaio² that works with augmented reality to identify elements in their A3 model. The user hovers over an element in and around the car and the smartphone computes the visual input to an information page about the function with details about functionality and maintenance. The augmented reality feature that Audi has presented can be a great asset for later versions of our concept.

3.2. Structure of the Application

Sacher determined that even drivers in their natural driving state are not aware of all functions in their vehicle. As our program aims at novice and advanced beginner users of a vehicle model, we assume that the knowledge of the functions and their respective input elements is lower than that of competent and proficient users. Sacher's experiment shows that this assumption is correct, when we regard the handling of the ACC by knowledgeable and novice users. Furthermore, from her results we take that most users are unmotivated to or uninterested in reading a manual description to improve their knowledge. The preferred method is to gain proficiency by "trial-and-error". In a moving vehicle, a "trial-and-error" approach can cause unnecessary distractions and lead to safety risks that are not assessable. Our program addresses the method by providing the user a one-on-one mapped representation of the vehicle's interior for the user to try out before entering a vehicle. The application is split up in different modes (Figure 3.2) to support both

¹J. McCarthy, "Audi Teaches Drivers Maintenance Tips with Augmented Reality App", <http://goo.gl/RKq0rq>

²Metaio - Augmented Reality Products and Solutions, <http://www.metaio.com/>

online as well as offline usage for the driver.

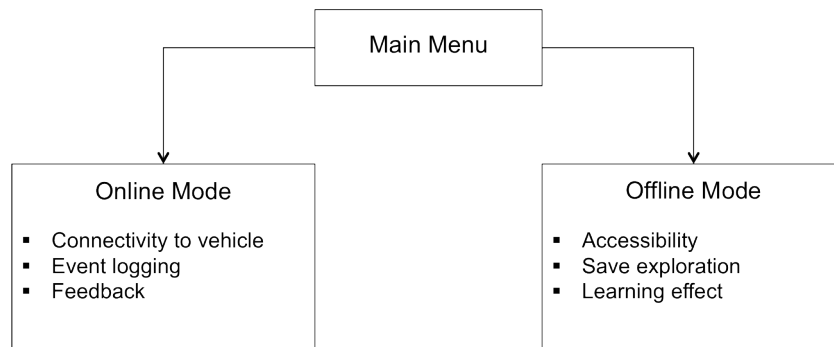


Figure 3.2.: Overview of the Menu Hierarchy. Application provides an Offline and Online Mode

3.2.1. Offline Mode

According to Gualtieri's five dimensions, a mobile application should be accessible everywhere. Although our application will be classified as a driver assistance program, it should not be available in-car only. To be able to learn about the functions of the vehicle with the "trial-and-error" approach, we want the user to have the possibility to use the application from any location. For this reason, the user can access the *Offline Mode* to familiarise with the functions of the vehicle and the placement of their input elements. In the *Offline Mode* (Figure 3.3), the user can choose between the *Exploration Mode* and a *Quiz Mode*.

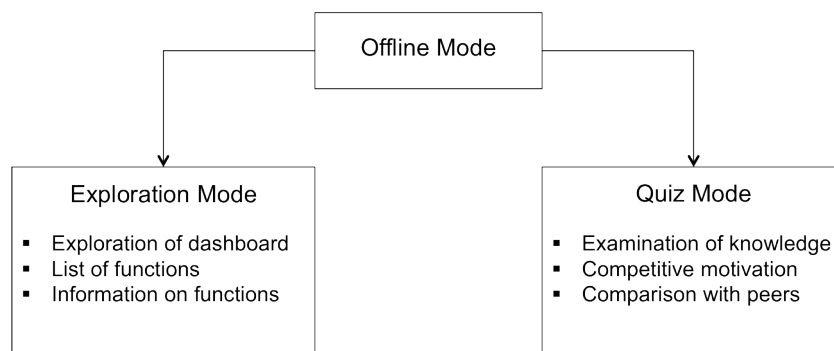


Figure 3.3.: Overview of the Offline Mode Hierarchy

The *Exploration Mode* gives the user the opportunity to explore the functions and the connected input elements of the vehicle. This can be done via the *Cockpit View* or the *Function View*. In the *Cockpit View*, the GUI is a mapped model of the vehicle's cockpit where the user can roam freely and find input elements by themselves (Figure 4.2). After clicking on the element, the user gets a visual feedback of how to operate the input element and which function it is connected to. In the

Function View, users find a list of functions that they have discovered so far. Missing objects are marked by a symbol to notify users about their discovery progress. Clicking on a specific function gives the user the visual feedback of the location and operation of the input element. The user has unlimited access to this mode so they always have the chance to return to the views to familiarise themselves with the functions.

The *Quiz Mode* helps the user remember and master the layout of the vehicle. By testing themselves, users can solidify and determine the level of their knowledge. Again, both *Cockpit View* and *Function View* are available. In the *Cockpit View* in *Quiz Mode*, input elements are highlighted and a multiple choice of functions is given. The user's task is to choose the right function according to the highlighted input element. The user has a limited amount of time to answer each question. Points are awarded for the right answer, bonus points are granted for quicker answers. The points of the test are accumulated in the end and are available for the user to compare in a high-score list. In the *Function View* in *Quiz Mode*, a function is presented to the user. The task is to find the right input element as quickly as possible. Points are rewarded for both speed and accuracy of the answers. The points off all tasks are accumulated to show the user their score and can be uploaded for comparison on a high score list.

3.2.2. Online Mode

The *Online Mode* (Figure 3.4) is available inside the vehicle. It is connected to the car's bus system to acquire the operations that the driver performs while handling the vehicle to assess the controls of secondary and tertiary tasks. From the research we can deduce that there should not be too many different visual outputs in the car to prevent distraction from the primary task. The *Online Mode* aims to work in the background as much as possible to guarantee a natural driving state and refrain from catching the driver's attention. The *Online Mode* is structured in three sub-modes, the *Quiz Mode*, the *Preset Mode*, and the *Background Mode*.

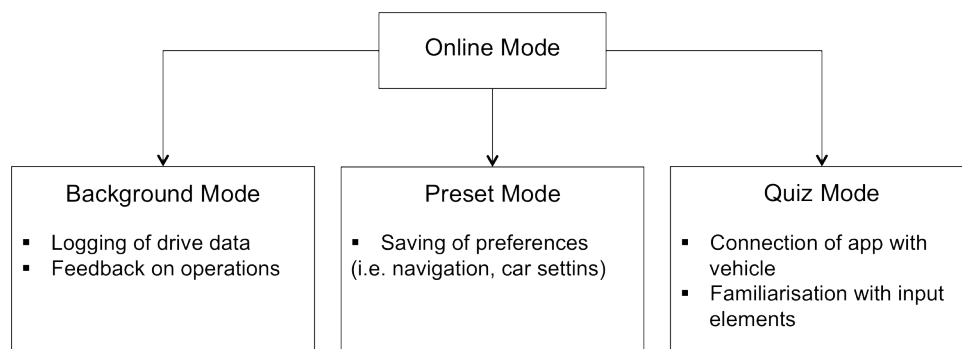


Figure 3.4.: Overview of the Online Mode Hierarchy

The *Quiz Mode* of the *Online Mode* works similarly to the one in the *Offline Mode*. However, since the application is connected to the vehicle and can collect data from the car, the *Quiz Mode* achieves a more realistic feeling. In the *Online Quiz Mode*, the application goes into *Function View* of the *Quiz Mode*. The application shows an individual function. Within a specific time, the user is supposed to operate the mapped input element that is connected to the function given by the application. The operation of the user can then be evaluated by the application due to the connectivity to the vehicle and the application gives direct feedback to the user if the operation performed was right. This is an essential part of the learning process, since it is taking the theoretical knowledge, gained in the *Offline Mode* and tests the knowledge in the real-life environment.

As suggested by Sacher, it is a convenient addition to the built-in infotainment system to remember a driver's favoured settings. By acquiring the setting of different car functions via the data logger, the application can give feedback to the user when the favourite settings have been reached. To remember a desired setting, the user can save the state of a function within the program when the vehicle is in standing position. While the car is moving, the *Preset Mode* will not be available to avoid distractions from the road. This should also motivate the driver to invest time before starting the vehicle to check the all functions for the wished settings and in long term, generate a behavioural change. When the vehicle is moving, the application goes into *Background Mode*. While it still acquires data from the operations, it does not pose a visual distraction to the driver. The acquired data can be used to assess the user's proficiency of the functions and give visual feedback of the average number of operations performed when the drive is over. From this data, the user can deduce if there has been an increase of proficiency due to the *Offline Modus* and the application can give the user advices for behavioural change to increase the driving safety.

3.3. Implemented Game Elements

As mentioned in Section 2.1, Sacher determined a lack of motivation and fun as a factor for the lack of interest in acquiring the knowledge about vehicle functions. In the previous section, we have shown the application's GUI as a means to provide the user the opportunity for the "trial-and-error" approach in a safe environment where they can familiarise themselves with the vehicle functions. In this section, we describe further implementations to the application to make the use more gameful and thus create a higher motivation for the user to utilise it. Several game elements are available in the Gamification theory. Here, we describe those that are used in the application.

3.3.1. Non-Game Context

We need to be aware how to create a meaningful application with which the user can relate so that we can create sustainable behavioural change. In order to do so, the underlying non-game context and the goal what the application wants to achieve need to be clear. From our research on previous work in Section 2.1, we have established that the automotive user is not fully aware of the spectrum of functionalities in the vehicle. In addition, the proficiency of task operation while driving determines the level of safety. The goal of the application therefore has to be to inform users of the vehicle functions and raise awareness of their operating behaviour inside the vehicle.

Lee et al. proposed four important factors of a game to incorporate into gameful design to achieve meaningful education [20]: a clear goal, rules, feedback and voluntary participation. Our application thus has to be able to successfully convey to the user the benefits of being aware of the spectrum of functionality their vehicle has to offer and how they are utilising it. For a successful use of the application, the user needs to connect with the underlying non-game context of our system and has to identify their own meaning in it.

In the Organismic Integration Theory(OIT), we have seen different stages of extrinsic motivation and intrinsic motivation (Figure 2.1, Section 2.3). Most Gamification systems apply on external regulation and introjection to motivate people to use the system. Rewards in forms of points and badges are used for external regulation to give the user tangible feedback on what he can achieve in the application. Another reason to keep score is for the ego-involvement, represented by a high score list. Games usually have some sort of scoring system implemented. In the single player modus, it is a milestone that the player must reach and an additional motivator to repeat the level and improve the score. In multiplayer modes, players will feel an even stronger motivation to compete against the score or directly against another player to surpass others and satisfy their innate need for assertion. The quiz modes of our application will include a scoring system for this very reason. Additional internet connectivity will assure that users can share their score with each others for higher competitive motivation and post their accomplishments. However, while we want to use a scoring system to create motivation, we will need to be cautious not to put too much focus on it so that it won't outshine the underlying non-game context which is of higher importance.

We will avoid an extensive use of a badge system as it usually promotes an organisation-centred design rather than a user-centred one. In a bad case, badges can look generic and are rewarded for repetitive and dull task which will get boring quickly. Although repetition is necessary for assimilating knowledge, asking users to e.g. do the quiz 10 times to get a badge won't make them concentrate on actually learning about the functions they are supposed to memorise. We will thus avoid creating repetitive tasks and hope for the user to internalise the goals of the application with their own and voluntarily interact with the application when they feel like doing so.

3.3.2. Game Interface Design Patterns

The game interface design patterns are usually implemented by badges, scores, leaderboards, or progress bars. Although in many cases, they are presented as a main and central component of Gamification, their main purpose is and should remain a visual feedback for the user to be aware of the progress. Our application will try to provide this visual feedback without putting emphasis on the game interface elements to a degree where the more important underlying non-game context will be eclipsed by it.

The Exploration Mode possesses a progress bar to notify the user of how many functions have been successfully found. This visual feedback about the own progress has shown to be a effective method for motivation. The user always has an up-to-date feedback about their accomplishment and can determine how much effort is still necessary. After discovering all functions, a badge is granted to the user. The badge should only be a visual representation that the exploration mode has been accomplished and should have a connection to the car. As an example, the badge system can be a garage where each badge is represented by a 3D car model that can be viewed from all angles. In further versions of this game, a variety of different car models can be implemented to give the user a gallery of known vehicles.

The Quiz Mode is shown in the menu view of the Offline Mode, but will be greyed out until 100% of the Exploration Mode has been achieved. Thus, the users are aware of the existence of an additional Mode, but have to complete the first step of the knowledge transfer first. The curiosity about the hidden mode motivates the user to accomplish the given task.

As mentioned in the last subsection, a scoring system will be created for the quiz modes to apply to the user's competitiveness. Badges will be given in form of content that is connected to the user's interest which in the case of a drive-assist application can be helpful videos about the vehicle, or pictures of classic car models or concept designs. A further use of badges avoided.

3.3.3. Game Design Patterns and Mechanics

The game mechanics are elements that commonly appear in games and concern the gameplay. They encourage challenge and strategic thinking in games, such as limited in resources for strategy games like *Age of Empires*³, or turn-based game-play in RPGs like *Final Fantasy*. These restrictions force the player to internalise with the mechanics of the game and give thought to an optimal way to solve the problem [32]. In our application, we apply the constricting game mechanic to the quiz in form of a time constraint. For each task of the quiz, the player gets a limited amount of time. However, the task will not be lost if the time constraint cannot be met. After the counter has run out, the user will still get the base points for accomplishing the task. The time will merely

³D. Shannon, "Age of Empires II Review", <http://goo.gl/ISMU0a>

count as a bonus if the user manages to find the function faster. As we implement a negative score for clicking on a wrong input element, the player will be forced to consider if being quick is worth risking negative points. Like this, new users can take their time and will still get an average score if they only manage to find the function without the time bonus, but more advanced players can challenge themselves and improve their score by being faster. The negative score will be small compared to both time bonus and base points since negative reinforcement can diminish motivation. It will be implemented to prevent users from just guessing about the functions and actually having to memorise them. Only an excessive number of false answers can nullify the total score, so users will not get discouraged by the negative score but use it as a reminder to be precise.

Novick and Ward's studies have shown that users' complaints about explanations of documentation is often based on the premise that all users have the same level of knowledge [10]. Our application will account for the difference in user experience by implementing a difficulty level for the *Quiz Mode*. The user has the ability to select between an easy, a medium and a difficult level. For both *Cockpit View* and *Function View* of the *Quiz Mode*, the difficulty level will determine the time that the user has to accomplish the tasks. For a higher difficulty, the user will have less time to find the answer than on an easier difficulty, but the time bonus for accomplishing the tasks will also be higher on a higher difficulty. Novice users can use the easy difficulty level and take more time while still experiencing a time bonus, but to achieve a higher score, users will have to select a higher difficulty.

3.3.4. Game Design Principles and Heuristics

The principles and heuristics of game design constitute the intangible guidelines for engagement with the application. Examples given for the principles and heuristics are enduring play, clear goals, and a variety of game styles [14]. The consideration and implementation of these elements help the gamified system exceed the dull experience of collecting badges and repeating unattractive tasks. Our application tries to meet these guidelines by having different modes of interaction, such as the free roam of the *Cockpit View* and *Function View* as well as the challenge from the *Quiz Mode*, and finally the helpfulness of the *Preset Mode* and *Background Mode*.

Chapter 4.

Implementation of the Concept

We have established a concept for a mobile driver assistance application in the previous chapter. For our research, we will implement a prototype version of the application for first testing and further evaluation. In this chapter, we describe the implementation of the prototype for Android devices. The prototype consists of the *Offline Menu* including the *Cockpit View*, the *Function View*, and the *Function View* for the *Quiz Mode*.

4.1. Design Specifics of the Application

Menu

The *Menu* (Figure 4.1) is kept simple for a quick overview. The three available functions in the prototype are displayed as buttons that lead the user directly to the function. Each button has a bold headline and an example picture of the function so that the user can find their desired function as quick as possible. The buttons also contain a brief description about the function.

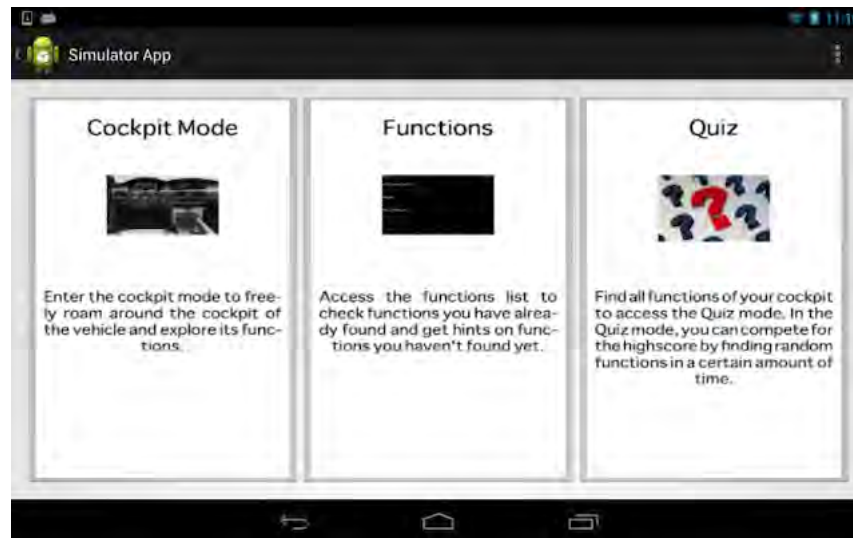


Figure 4.1.: Offline Menu of the Prototype Application. Implemented Cockpit View, Function List, and Quiz Mode.

4.1.1. Cockpit View

For our experiment, we had access to a BMW series 5 model vintage 2005-based simulator from the department of Human-Machine Communication (Lehrstuhl für Mensch-Maschine-Kommunikation) of the Technische Universität München. The application's *Cockpit View* is created to represent the exact interior of the experiment environment. A picture was taken as template to remodel the background and each input element individually (Figure 4.2). The decision to design the *Cockpit View* in this realistic manner was to stay as close to the original as possible so that the user can make a connection between the application and the real dashboard.

On the upper right corner of the *Function View* the progress is shown. A total of 32 elements are implemented in the prototype, the number left of the forward slash is the number of elements that the user has found so far. By clicking on a mapped input element, the user will be forwarded to the description page of the function and the selected element will be highlighted by a white outline as visual feedback for the user to keep track of functions that have been selected once (Figure 4.3).



Figure 4.2.: Comparison of Real Life Dashboard (Top) and Implemented Cockpit View (Bottom)

4.1.2. Function View

Each input element that represents a function has an own description page (Figure 4.4). The layout of the page is consistent for all elements with the title of the function and the description on how to operate the function on the left and a picture of the input element on the right.

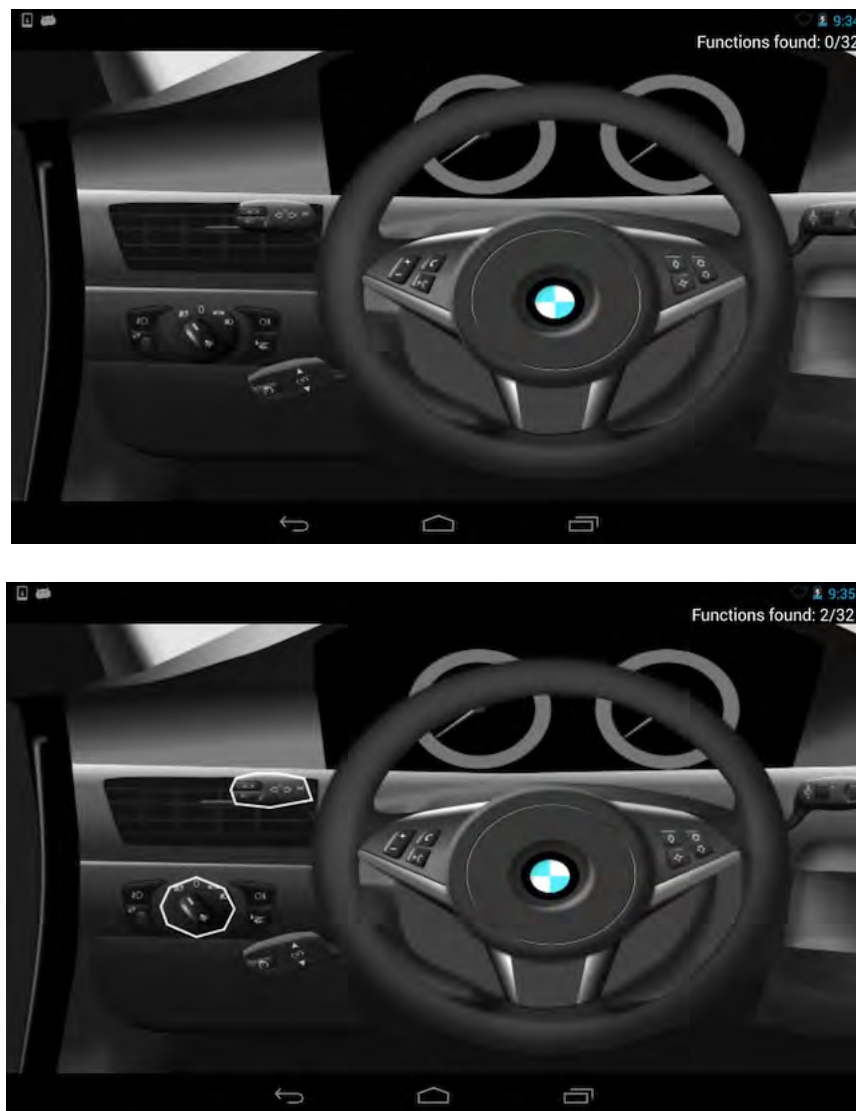


Figure 4.3.: Zoomed display of the Cockpit View (Top) with white outline on discovered functions (Bottom)

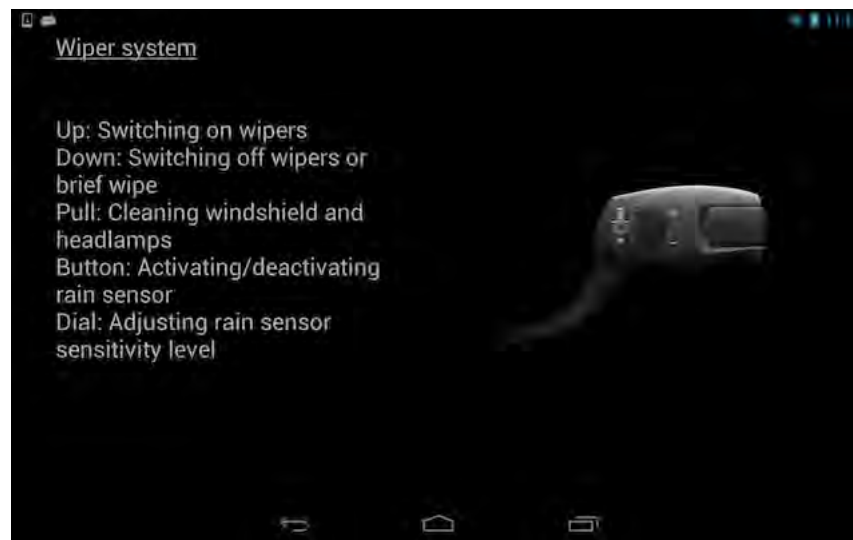


Figure 4.4.: Description Page of Functions with the Name of the Function, the Description of its Operation, and the Visual Representation

The *Function View* is shown as a list where functions that have not been found are displayed in a dark grey. When clicking on a dark grey item, a message with a hint where to find the element in the car will pop up (Figure 4.5). Functions that have been found will be shown in a white font. Clicking on white items will lead the user to the description page of the function.

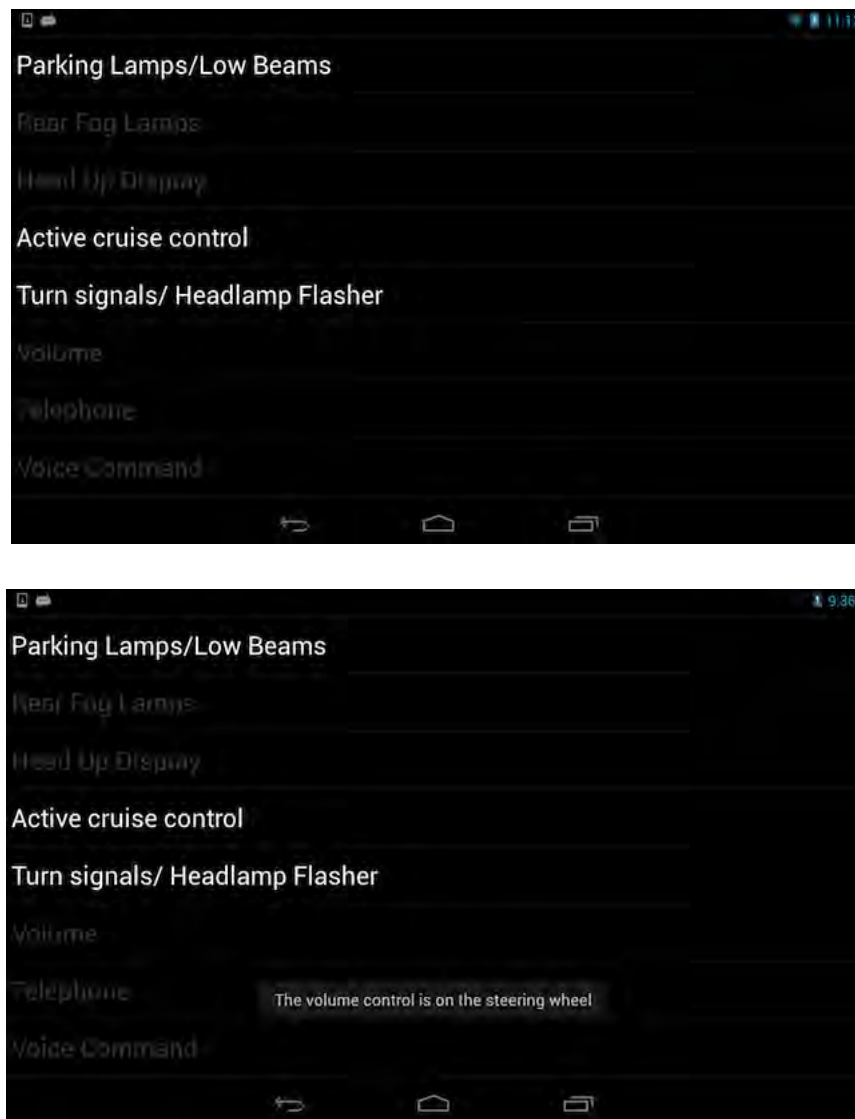


Figure 4.5.: List of Functions. Functions with white font can be accessed, functions with grey font indicate missing functions. Clicking on a grey function triggers a toast with a hint

4.1.3. Quiz Mode

The *Quiz Mode* shows the user the cockpit view with the quiz elements in the upper left corner. The quiz elements consist of the control element that needs to be found and the current cumulated score of the user. The user gets a visual and auditory feedback upon selecting an element. For right answers, the user receives a green tick while wrong answers will trigger a red cross on the lower middle of the screen as can be seen in Figure 4.6. The white outline of the elements has been kept in the prototype for an easier execution of the quiz. In further versions, the outline can be removed by selecting a higher difficulty.

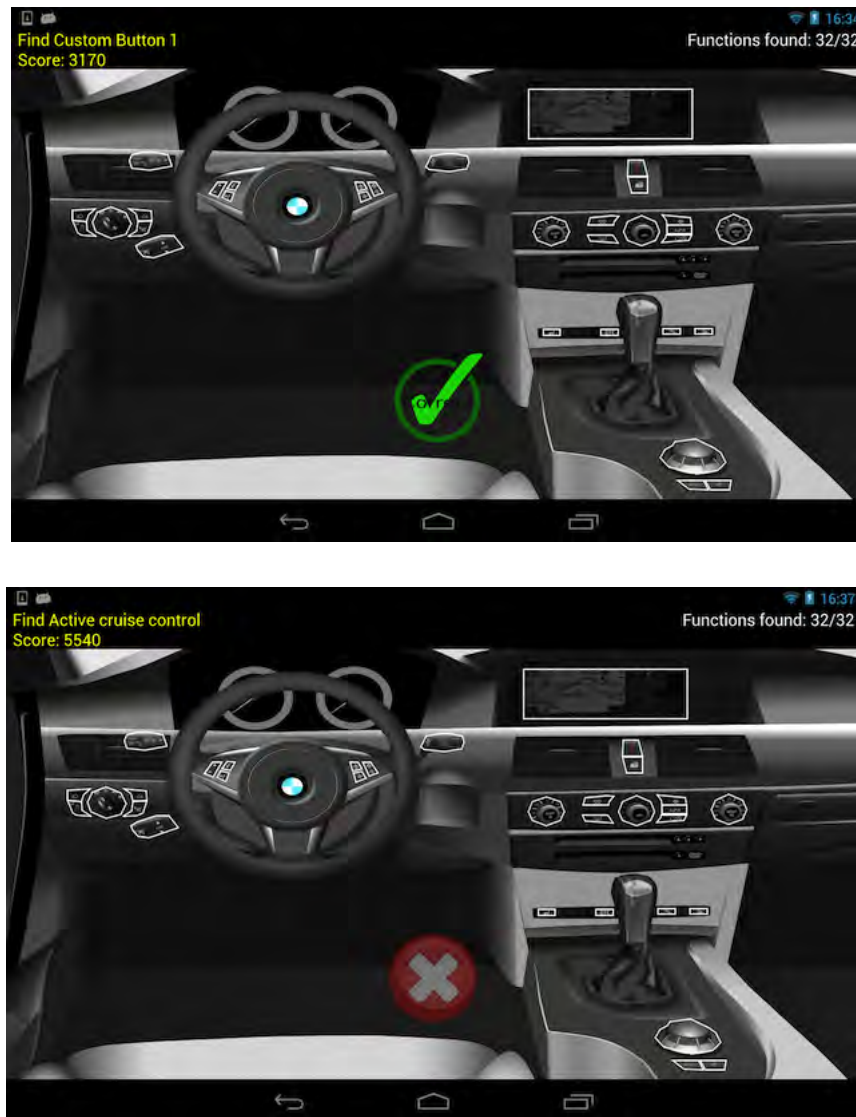


Figure 4.6.: Quiz Mode triggers a Green Tick on a Right Answer (Top) and a Red Cross on a Wrong Answer (Bottom).

After finishing the tasks of the quiz, the user will be taken to the scoreboard. This view shows the user how the final score is structured. The user receives a base score for accomplished tasks which they will get in any case. An additional time bonus represents how quickly the user was able to finish the tasks and the negative score is cumulated from all wrong answers. If the user manages to reach a new high score, it is shown to them beneath the total score. In the score view, the user has the options to either retake the quiz or go back to the main menu.

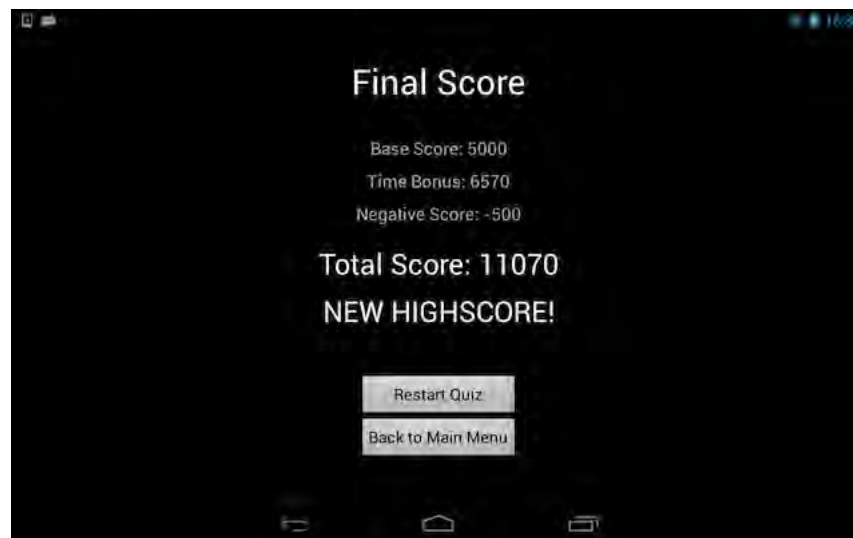


Figure 4.7.: Score Page of the Quiz. Shows Score Elements for the Final Score. "NEW HIGHSCORE!" Displayed when a new high score is achieved.

4.2. Specifics of Implementation in Android

4.2.1. Mapping of Elements

After implementing the base structure of the Android application, we encountered the issue of how to make the various input elements clickable, since the default button function of Android does not permit custom shaped buttons. We have therefore implemented a `Polygon.java` class that allows us to create mapped areas with predefined corner points. The polygon sets up a list array where points are defined by their x- and y-coordinate. The points are connected in the given order as can be seen in the Listing 4.1 until the last point that is connected with the starting point again. Each input element of the dashboard has been mapped in this way to represent their individual shape as best as possible. After the area of the input element is closed by the polygon mapping, it is assigned to its `ControlElement` class which defines a key and an ID for the input element.

Due to the implementation of the `Polygon.java` class instead of defining the input elements as buttons, we had to use the `OnTouchListener` instead of the `OnClickListener`. This led to the execution of the function view firing multiple times when clicking on an input element because the touch event registered the gesture more than once before the event could be executed. To prevent this, we shifted the execution of the new view into the `ACTION_POINTER_UP` event when the finger is removed from the screen and defined a pointer index for each gesture input (Listing 4.2).

Listing 4.1: Example of polygon mapping (CockpitActivity.java)

```
<275> pointsList = new ArrayList<Point>();
<276> pointsList.add(new Point(184,652));
<277> pointsList.add(new Point(185,617));
<278> pointsList.add(new Point(252,613));
<279> pointsList.add(new Point(232,634));
<280> pointsList.add(new Point(226,656));
<281> ControlElement e = new ControlElement(ControlElementID.LIGHT_LEFT);
<282> e.setPoints(pointsList);
<283> controlElementsList.add(e);
```

Listing 4.2: Prevent Touch Event from Firing Multiple Times (CockpitView.java)

```
<302> case MotionEvent.ACTION_POINTER_UP: {
<303>     final int pointerIndex = (me.getAction() &
        MotionEvent.ACTION_POINTER_INDEX_MASK)
<304>         >> MotionEvent.ACTION_POINTER_INDEX_SHIFT;
<305>     final int pointerId = me.getPointerId(pointerIndex);
<306>     if (pointerId == mActivePointerId) {
<307>         final int newPointerIndex = pointerIndex == 0 ? 1 : 0;
<308>         lastTouchX = me.getX(newPointerIndex);
<309>         lastTouchY = me.getY(newPointerIndex);
<310>         mActivePointerId = me.getPointerId(newPointerIndex);
<311>     }
<312> }
```

Listing 4.3: Example of Editing the Shared Preferences (FunctionActivity.java)

```
<168> protected void onResume() {  
<169>     super.onResume();  
<170>     SharedPreferences preferences =  
        PreferenceManager.getDefaultSharedPreferences(this);  
<171>     Editor editor = preferences.edit();  
<172>  
        editor.putBoolean(ControlElement.getKeyFromOrdinal(currentElementID), true);  
<173>     editor.commit();  
<174> }
```

4.2.2. Shared Preferences

Since we are applying several activities in the application that need access of the same information, we needed to implement the Shared Preferences. The Shared Preferences create a single instance of a set of preferences that all clients (activities) share¹. Modifications made to the preferences are done by the Shared Preferences.Editor to ensure that the values are in a consistent state when committed to the storage. The code example in Listing 4.3 shows how the Shared Preferences are edited. In this example, the input element that has been selected for the first time is assigned a TRUE state so that the application registers that it has been selected. The value of this shared preference updates the progress and displays the element's white outline in the cockpit view.

To return values from the Shared Preferences, we apply the get Method. The returned values must be immutable by the application and can only be edited by the Shared Preferences.Editor. The code excerpt in Listing 4.4 shows an example of the get method that we use for application to calculate the progress bar. The boolean value, if an element has been selected, is returned from the Shared Preferences and the value progress is updated for all elements.

Another value that is saved in the Shared Preferences is the highscore of the quiz so it can be shown and reset in the main menu. The progress of the *Cockpit View* can also be reset in the main menu. When the user selects the option, the application returns the boolean values of the ControlElement class from the Shared Preferences and resets them to FALSE.

4.2.3. Pinch-to-Zoom and Drag

Compared to the entirety of the *Cockpit View*, some of the input elements are very small and difficult to reach. This is the reason why we decided to implement a pinch-to-zoom function in the

¹Android Developers, Shared Preferences, <http://developer.android.com/reference/android/content/SharedPreferences.html>

Listing 4.4: Example of Returning Values from the Shared Preferences (CockpitView.java)

```

<345> private int getProgress() {
<346>     int progress = 0;
<347>     SharedPreferences preferences =
        PreferenceManager.getDefaultSharedPreferences(mContext);
<348>     for (int i = 0; i <= 31; i++) {
<349>         if
            (preferences.getBoolean(ControlElement.getKeyFromOrdinal(i), false))
<350>             progress++;
<351>     }
<352>     return progress;
<353> }

```

Listing 4.5: Implementation of Scaling in Android (android.graphics.Canvas)

```

public final void scale(float sx, float sy, float px, float py) {
    translate(px, py);
    scale(sx, sy);
    translate(-px, -py);
}

```

application (Figure 4.3). We faced a problem with the implementation since the method provided by Android could not fulfil our requirements. In Listing 4.5² we see how the method

```
canvas.scale(float sx, float sy, float px, float py)
```

is defined in the Android API with s_x and s_y being the amount to scale in X- and Y-coordinates and p_x and p_y the X- and Y- coordinates for the pivot point, i.e. the point that is not being scaled and marks the center of the two finger pinch the user scales from.

The problem we face with this method is that the whole canvas is being translated by (p_x, p_y) first,

$$T_p v = \begin{bmatrix} 1 & 0 & p_x \\ 0 & 1 & p_y \\ 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{bmatrix} p_x + x \\ p_y + y \\ 1 \end{bmatrix}$$

then scaled

$$S_s T_p v = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \begin{bmatrix} p_x + x \\ p_y + y \end{bmatrix} = \begin{bmatrix} s_x p_x + s_x x \\ s_y p_y + s_y y \end{bmatrix}$$

and then translated back.

²Android API, Canvas.java, [goo.gl/d3D5t3](https://developer.android.com/reference/android/graphics/Canvas.html#scale(float,%20float,%20float,%20float))

Listing 4.6: Factoring of the Image-To-Device Ratio (CockpitView.java)

```

<121> if (canvasHeight != heightOriginal && canvasWidth != widthOriginal) {
<122>     xScaling = canvasWidth/widthOriginal;
<123>     yScaling = canvasHeight/heightOriginal;
<124>     for (ControlElement ce : controlElementsList) {
<125>         pointsList = ce.getPoints();
<126>         for (Point p : pointsList) {
<127>             p.x = (int) (p.x * xScaling);
<128>             p.y = (int) (p.y * yScaling);
<129>         }
<130>     }
<131> }
<132> else {
<133>     xScaling = 1.0f;
<134>     yScaling = 1.0f;
<135> }
<136>     is_initialized = true;

```

$$T_{-p}S_sT_pv = \begin{bmatrix} 1 & 0 & -p_x \\ 0 & 1 & -p_y \\ 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} s_x p_x + s_x x \\ s_x p_y + s_x y \\ 1 \end{pmatrix} = \begin{pmatrix} -p_x + s_x p_x + s_x x \\ -p_y + s_x p_y + s_x y \\ 1 \end{pmatrix} = \begin{pmatrix} (s_x - 1)p_x + s_x x \\ (s_x - 1)p_y + s_x y \\ 1 \end{pmatrix}$$

It is not being taken into consideration by the Android API that the second translation is with scaled values. This leads to the result that the entire canvas is translated by a factor of $(s_x - 1)p$ in x- and y-direction. The consequence is that after the picture is zoomed, the entire coordinate system is shifted by this factor, i.e. when dragging the picture to the (0,0)-coordinates, it is not accurate but somewhere in the middle of the picture. To solve this issue, we implemented following steps.

During the initialisation of the application, the proportions of the cockpit view are scaled compared to the proportions of the mobile device. All subsequent input elements, the coordinates for the elements' mappings, and the gesture inputs from the user are multiplied with the scaling ratio's factor (Listing 4.6).

For the canvas transformations, first the initial canvas is saved and the scaling factor is then applied in the way we previously described (Listing 4.7). The `maxTranslation` values are calculated and taken as the maximum coordinates that the image can be moved to the right in x-direction and down in y-direction. The vector `(posX, posY)` is the updated coordination of the gesture input. It is the value of the (x,y)-coordinates of the last gesture input minus the value of the first gesture input during a swipe gesture. Therefore, a movement to the right gives back a negative x-value while a movement to the left gives a positive value. If `posX` reaches the maximum `maxTranslationX`, it will be constantly updated with the maximum value. The values `originX` and `originY` describe the difference between the origin of the scaled image relative to the origin

of the original image (Listing 4.8). If the value is reached by a swipe movement to the left of the screen, `posX` is updated with `originX` and no further movement to the left happens. The same calculations apply for the y-direction with swipe movements down respectively for the right movement of the x-direction and movements up for the left movements of x.

The two finger pinch movement is defined in the `ScaleListener` class. The `getScaleFactor()` function automatically calculates the scaling factor from the span difference between two fingers during a pinch gesture. The value of the `getScaleFactor()` function is then written to the value `zoom_scaling_factor` and restricted to a range of minimum 1 and a maximum zoom value of 4. As we can see from the code excerpt in Listing 4.8, the pivot points for the scaling are only initially calculated when the picture is not zoomed. The reason for this implementation is that there was no accurate way to implement a new calculation of the pivot points in between two pinch zoom gestures without moving the image origin. The choice to go with this slightly less elegant method is that most users tend to only zoom outside of the centre of the device screen when the picture is not zoomed. Additional pinch zoom gestures made when the picture is zoomed usually go further in the direction the user initially wanted to go to. When zooming out, users generally pay less attention to the direction of the zoom. During our experiment, we had no input from any participant that the pinch zoom function was slightly off which verifies this hypothesis.

4.2.4. Other Implementations

Extra Intent

The control elements can be selected in the *Cockpit View* or the *Function List*. Upon selection, the application forwards the user to the `FunctionActivity` seen in Figure 4.4. To account for the high number of control elements, we used the extra function of the intent. The ID of the selected control element is written in an extra intent in the *Cockpit View* or *Function List* (Listing 4.9),

Listing 4.9: Setting Extra Intent (CockpitActivity.java)

```
<198> intent.putExtra("ElementID", position);  
<199> startActivity(intent);
```

and recovered in the `FunctionActivity` (Listing 4.10).

Quiz feedback

The *Quiz Mode* features feedback for the user when a correct or wrong element is selected. The feedback that is implemented is both visual and auditory. The visual feedback is a toast action, i.e. a pop up, of either a green tick for a right answer or a red cross for a wrong answer (Figure 4.6).

Listing 4.7: Scaling and Translation of the Canvas

```
<150> canvas.save();
<151>
<152> //Zooming Image
<153> canvas.scale(zoom_scaling_factor, zoom_scaling_factor, cX, cY);
<154>
<155> //Calculating the maximum translation
<156> float cw = (float) canvas.getWidth();
<157> float ch = (float) canvas.getHeight();
<158> maxTranslationX = (cw * zoom_scaling_factor - cw) / zoom_scaling_factor - cX
    * (1 - 1/zoom_scaling_factor);
<159> maxTranslationY = (ch * zoom_scaling_factor - ch) / zoom_scaling_factor - cY
    * (1 - 1/zoom_scaling_factor);
<160>
<161> if (posX < -maxTranslationX) {
<162>     posX = -maxTranslationX;
<163> }
<164> if (posX > originX) {
<165>     posX = originX;
<166> }
<167> if (posY < -maxTranslationY/zoom_scaling_factor) {
<168>     posY = -maxTranslationY/zoom_scaling_factor;
<169> }
<170> if (posY > originY/zoom_scaling_factor) {
<171>     posY = originY/zoom_scaling_factor;
<172> }
<173>
<174> if (zoom_scaling_factor==1.0f) {
<175>     posX = 0;
<176>     posY = 0;
<177> }
<178>
<179> //Dragging image
<180> canvas.translate(posX, posY);
<181>
<182> canvas.drawBitmap(backgroundImage, 0, 0, pBackground);
```

Listing 4.8: Implementation of the ScaleGestureDetector (CockpitView.java)

```
<321> private class ScaleListener extends
    ScaleGestureDetector.SimpleOnScaleGestureListener {
<322>     @Override
<323>
<324>     public boolean onScale(ScaleGestureDetector detector) {
<325>         zoom_scaling_factor *= detector.getScaleFactor();
<326>         //Calculation of zoom factor with maximum zoom of 4 times
<327>         zoom_scaling_factor = Math.max(1.0f,
            Math.min(zoom_scaling_factor, 4.0f));
<328>         // Centre of zoom calculated only initially
<329>         if (zoom_scaling_factor == 1.0f) {
<330>             cX = detector.getFocusX();
<331>             cY = detector.getFocusY();
<332>         }
<333>         //Calculation of image origin relative to screen origin
<334>         originX = cX * (1 - 1/zoom_scaling_factor);
<335>         originY = cY * (1 - 1/zoom_scaling_factor);
<336>
<337>         invalidate();
<338>
<339>         return true;
<340>     }
<341> }
```

Listing 4.10: Recovering Extra Intent (FunctionActivity.java)

```
<25> Bundle extra = getIntent().getExtras();
<26> int ElementID = extra.getInt("ElementID");
<27> currentElementID = ElementID;
```

Listing 4.11: Cancelling Toast after 500ms (CockpitActivity.java)

```
<231> toast.show();
<232>
<233> Handler handler = new Handler();
<234>     handler.postDelayed(new Runnable() {
<235>         @Override
<236>         public void run() {
<237>             toast.cancel();
<238>         }
<239>     }, 500);
```

The usual duration for a toast action is four seconds for a `Toast.LENGTH_LONG` and two seconds for a `Toast.LENGTH_SHORT`. Either option is too long for a fast paced-quiz modus. We have therefore implemented a handler that cancels the toast after half a second (Listing [4.11](#)).

Chapter 5.

Experiment Setup

In this chapter, we will explain the experiment environment, the setup of the experiment tasks, and which criteria we have chosen for the evaluation. The experiments were conducted at the driving simulator of the Institute for Human-Machine-Communication of the TUM (Lehrstuhl für Mensch-Maschine-Kommunikation, MMK).

5.1. Specifics of the Driving Simulator

The driving simulator consists of the front half of a BMW series 5 car (model E60). The bus system of the vehicle has been modified for easy CAN bus (controller area network) access and the displays inside the vehicle have been replaced. The setup of the simulator room can be seen in Figure 5.1.

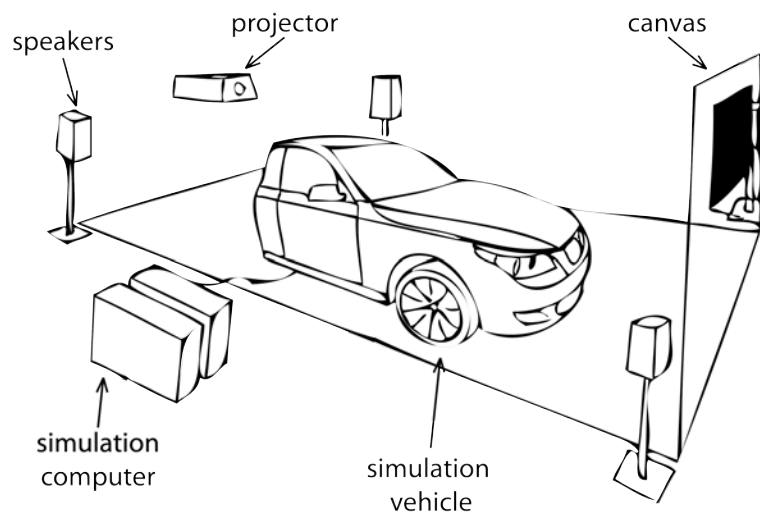


Figure 5.1.: Setup of the Driving Simulator¹

5.1.1. Visual setup

The electronic instrument cluster and the iDrive display are replaced by monitors, the front view outside the vehicle is displayed by a projector and canvas setup. No side or back views are implemented in the setup (Figure 5.2). The three displays are driven by one computer with a fourth monitor in a separate room for the conductor of the experiment. The simulation computer handles the four monitor setup as well as the controls for pedals and the steering wheel in the simulation vehicle. The additional input from the controller for the iDrive menu and buttons on and around the multi-function steering wheel are handled by a second computer.



Figure 5.2.: Inside View from the Simulator Car. The Control Display and Electronic Instrument Cluster are replaced by Monitors, the Front View is projected on a Canvas.

5.1.2. Audio Output

The experiment setup provides audio output for the driving simulation application, the original audio system of the vehicle, the head unit and multimedia computer, and the microphone for the experiment conductor. The mixer handles all sound inputs and outputs the audio on a 4.1 surround system around the vehicle and further speakers inside the vehicle.

¹MMK Driving Simulator, <http://www.mmk.ei.tum.de/layout.php?LangExt=&selectedMain=Verschiedenes&selectedSub=CARLAB>

5.1.3. Communication between Car and Simulator

The functions connected to the controller and the central information display for the iDrive system, the multi-function steering wheel, light controls, active cruise control, the electronic instrument cluster, and the head unit run on the K-CAN and PT-CAN of the vehicle's controller area network (CAN) (Figure 5.3).

The controller area network (CAN) is an asynchronous, serial field bus system that allows real-time communication between all members of the bus topology [33]. It is suitable for the communication in the control system of the vehicle due to its ability of sending a high number of small messages. The CAN system additionally possesses a high resistance against electromagnetic and environmental disruptions, and fast error detection and correction which makes it ideal for the dynamic conditions inside a vehicle. Each member of the CAN bus topology is described as a node, the communication between nodes is made via three twisted lines, the lowspeed line, the highspeed line, and the ground line. In this case, the K-CAN ("vehicle body-CAN") is the lowspeed line and the PT-CAN ("PowerTrain-CAN") is the highspeed line. A constant voltage difference between the high- and low-lines of the CAN bus marks a logical 1 as the idle state of the system. To signal the start of a message with a logical 0, the voltage difference is changed. The advantage of this method is that variations in voltage usually affect all lines equally and will cause less errors in this case.

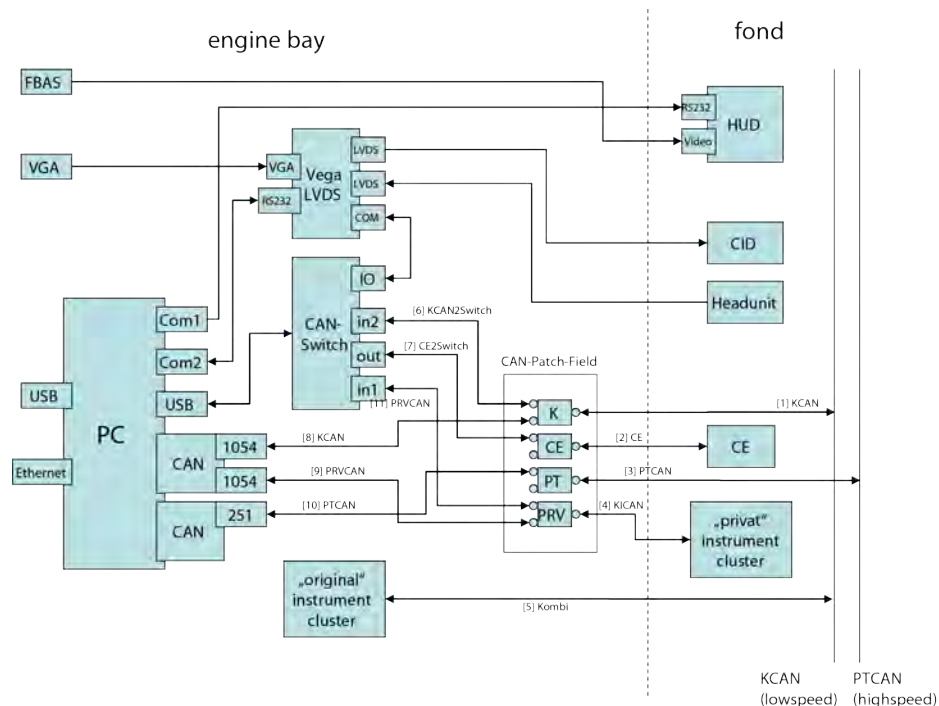


Figure 5.3.: Overview of Communication between Car and Simulator. Implementation of a 'Private' CAN for Reading and Manipulating Signals in Vehicle. [34]

The K-CAN and PT-CAN of the vehicle are connected with the communication computer for the simulation purposes. Next to the original CAN bus, a "private" CAN is implemented so that the signals from the iDrive controller do not collide with the original system. The original CAN bus system still needs to run in the background as the original electronic instrument cluster needs to send safety-related signals to the vehicle. Therefore, the original electronic instrument cluster is hidden in the engine bay with further simulation equipment, the replacement display is hooked up to the private CAN. The communication computer is connected to the vehicle with three CAN channels leading to the original bus, the iDrive controller and the electronic instrument cluster. The input and output to the CAN bus of the vehicle takes place via an Ethernet connection. The input from the control elements in the vehicle are sent via the Ethernet connection by multicast and can be received by any node in the network. The additional application "LFE_Mockup" sends and receives the vehicle's information on speed, rotations per minute (rpm) and further motor data.

5.2. Layout and Development of the Experiment

In this section, we present the layout of the experiment and afterwards the steps we took to develop the layout.

5.2.1. Layout of the Experiment

The experiment is structured as follows:

Pre-Experiment Questionnaire

The questionnaire before the experiment assesses the participant profile. Mainly, the information we acquire is about their demographics, their experience and behaviour with vehicle operation and their behaviour with mobile devices. The pre-experiment questionnaire can be found in [Appendix A](#).

Exploration of the Mobile Application

After the initial questionnaire, the participants will be divided into a control group and an experiment group. The control group will not use the mobile application before the experiment. The experiment group will then have a period of ten minutes to explore the proposed mobile application. The participants are being instructed on the functionality of the application and given reminders that finding all input elements will unlock the quiz mode. Otherwise, no specific tasks are given.

Driving Tasks

Both control group and experiment group get the same tasks in the driving simulator. The experiment in the simulator consists of three rounds on a course in the Lane Change Task simulation [35]. The first round serves as the ground truth while the second and third round implement operation tasks next to the driving task. After each round, we ask the participant for a subjective assessment of their mental workload with the NASA Task Load Index [36]. The mental workload assessment can be found in [Appendix B](#).

Post-Experiment Questionnaire

After the driving tasks, the participant is asked to fill out an assessment on the driving and operating tasks of the experiment, and an assessment on the mobile application for participants of the experiment group. Next to the assessment questions, the participants have a free form for additional on the test and on the application. An additional short interview is conducted with each participant to capture information that are unclear in the written feedback or that were not mentioned before. The post-experiment questionnaire can be found in [Appendix C](#).

5.2.2. Development of the Experiment

In this section, we explain the steps we took to get to the presented layout of the experiment in the previous section. As field studies that involve participants require a considerable amount of time and effort, it is important to first know what the reasons are for conducting the study and what the conductor wishes to learn from the outcome [37].

Determining the Type of the Field Study

First off, we decided which type of field study we are conducting to determine the research questions of our study. Common types of field studies are [37]:

- Studies of current behaviour: What are people doing now?
- Proof-of-concept studies: Does my novel technology function in the real world?
- Experience using a prototype: How does using my prototype change people's behaviour or allow them to do new things?

We are aware that due to the early stage of our application and the limited resources we have, no extensive field study can be conducted. A proof-of-concept study can usually be done in a shorter time frame to validate the feasibility of an approach or a prototype. Studies on current behaviour strive for an understanding of current behaviour towards technology and finds implications for future technology. A study that examines the participants' experience using a prototype is conducted over a long period to capture all aspects of the prototype for further development.

Due to the aforementioned restrictions in our study, we have to limit the possibilities that a full-fledged study in one of those types can achieve. For our study, we try to briefly examine the participants' behaviour concerning vehicle operation and technical gadgets and assess if the concept of our application can fit with users' behaviour. We conduct a driving experiment with different participant groups to establish a verification of the proof-of-concept for our prototype. As the overall experiment is very short, it will be difficult to pinpoint long term implications of the use of our application. We therefore have to rely on feedback and interviews for an assessment of the prototype and further development points.

Goals of the Field Study

After being aware of the type of study we want to conduct, we specified the goals that the study should achieve. We have established that it should primarily be a proof-of-concept study, while we also incorporate elements of the behavioural and experience study. We take into consideration the purpose of our application once more:

- Educate users in the functionality of the car interior
- Raise proficiency in the use of these functions
- Consequently reducing mental workload while operating multiple functions and thus improving safety
- Recommending a change in driver behaviour
- Motivation to learn through playfulness and competitiveness

To evaluate if the purpose of the application is captured by the implementation, the study should fulfil following indicators:

- Difference between users that have experienced proposed system and users ignorant to the system
- Subjective users' rating of usefulness and enjoyment of system
- Users' suggestion for improvements of system

The data we will collect to verify the indicators will be quantitative results from the driving tasks and qualitative results from questionnaire and interview.

Research Questions

We further define which research questions about the feasibility of our application we want answered by the study.

The research questions we pose are:

1. Is the Offline *Quiz Mode* enough to familiarise with the vehicle user interface?
2. Does the offline training in the *Quiz Mode* improve the driving performance of the participants?
3. Do the Competition aspects of the Gamification have increasing safety-impairing effects?

The first question is whether the recreated virtual car interface of the cockpit in the offline mode can be compared to the real car interface. The offline mode of the application has the purpose to remotely educate the user without them having to be inside the vehicle. Thus, it is helpful to know if the virtual cockpit is enough to familiarise the user with the interior of the car.

Directly connected to the efficiency of the application as well as a further research question is whether the training in the offline mode has a direct effect or improvement of the driving performance of users who experience the application compared to those that do not use the

application. We use a direct comparison of the results of the driving task between the control group and the experiment group for this research question.

Furthermore, we want to analyse if the Gamification aspect will have safety-impairing effects on the driving performance of the user. As mentioned before on page 28, Gamification examples in the driving environment has led to unsafe driving behaviour because users were more focused on the challenge than on safe driving. We want to explore if the utilisation of Gamification while driving has negative effects on the manoeuvring of the vehicle during the driving task. The second and third round of the Lane Change Task simulation are used to answer this question. During the second round, the participant experiences the additional operating tasks parallel to the driving task. The comparison of the second round with the ground truth will show the impact of the visual distraction of a quiz modus while driving. Before the third round, the participant is told that they can increase their score for a high-score list. This setup shows us the implications of competitive behaviour on the safety of the driving.

Participant Profile

Another important factor to consider when designing the study are the participants criteria. Depending on what user group the proposed system is addressing, demographic data such as age, gender, or technology use and experience need to be taken into consideration for a meaningful proof-of-concept study.

We are proposing a mobile drive-assist application which determines that the user will be of age. For the results to cover as much data as possible, a wide range in age would be appropriate to study the effects of the application both on users that belong to the digital generation as well as users that are not as familiar with mobile devices. Additionally, the age is an indicator for the driving experience that the participants have. We expect that younger participants will be more familiar with the use of mobile devices, but will lack experience in vehicle handling. Ideally, the participants' age would include novice drivers with less than 5 years driving experience, average drivers under the age of 35 that still belong to the digital generation, and experienced drivers over the age of 35 to test the application on users that are more proficient in vehicle handling and less in mobile device handling.

Information on the experience in vehicle operation and mobile device handling of the participants will also be determined. The experience in vehicle operation should show how much driving experience the participant has and what functions are regularly used while driving. We set the driving experience as an important factor as we expect that more experienced drivers will perform better than novice drivers. This hypothesis is based on Sacher's evaluation that experienced drivers have a lower mental workload than novice drivers when operating common secondary functions such as the signalling process [4]. The information on the vehicle user interface handling we expect

to collect shall verify Sacher's findings and show what aspects our application needs to focus on in further versions.

We will collect the mobile device handling behaviour of the participants to determine whether such an application has an actual demand in real life situations. The information we need to collect in this aspect is what kind of applications are frequently used to determine if our proposed application fits into the category of interest of the participants. Furthermore, we will collect information on what kind of mobile devices are frequently used by the participants. For our mock trial, the application is designed specifically for a Nexus 7 tablet, but it is to be determined if the use of tablet devices is as common as smartphones. Further information is collected on general user behaviour concerning interest in technology, the willingness for problem solving and consulting documentation, as well as the competitiveness of the participants. This information determines if the context of our proposed application fits the criteria on improving documentation usability and raising motivation to participate through competitive Gamification elements.

The ratio between male and female drivers is roughly equal according to latest mobility studies in Germany. Thus, the ratio between male and female participants in the study can be equal so that it will be an independent variable.

The expected duration of the experiment per participant is between 30 and 45 minutes and we assume the tasks to not be too strenuous for the participants. The compensation for the participants can therefore be relatively low to justify the needed time and effort. We have decided to give each participant a small gift voucher for Amazon (value 5 Euro).

Mental Workload Assessment

We have established in Section 2.1 that the operation of additional tasks parallel to the driving task increases the mental workload of the driver. During our study, the participants have to perform additional operation tasks parallel to the driving task. As all tasks use the same working memory resource of the driver [38], we expect that additional tasks will also increase the mental workload for the driver. To verify this, we implement a subjective measurement with the NASA-Task Load Index (NASA-TLX). The NASA-TLX was developed by NASA and contains six subscales: mental demands, physical demands, temporal demands, own performance, effort and frustration [36]. The NASA-TLX form can be found in Appendix B. The participants are asked to fill out this form after each round of the driving simulator. The comparison between the participant's self assessment between the rounds show us if the dual tasks of manoeuvring and operating the vehicle puts additional mental workload on the participant as is suggested in the theory.

5.3. Specifics of the Driving and Operating Tasks

To verify any impact of the proposed mobile application, we conduct an experiment in the driving simulator and compare the results of a control group and an experiment group that uses the mobile application before the simulator. During the simulation, the participants are asked to execute a driving task with additional tasks on the vehicle's user interface.

5.3.1. Lane Change Task

For the simulation, we use the Lane Change Task (LCT) as the background program. The driving simulation was created within the ADAM Project [39] and is a basic simulation for studies involving in-vehicle infotainment systems (IVIS). The simulation consists of a straight road with three lanes that the participant needs to change to when asked.

Figure 5.4 shows a screenshot of the LCT driving task. The tasks are given to the participant as a white sign on either side of the road, indicating the three lanes with the requested lane shown as an arrow. Upon perceiving the right lane, the driver's task is to change the lane as fast and precise as possible and otherwise keep the ideal track on the right lane. The driving speed of the simulation is usually limited to 60 km/h, the whole track includes 18 lane changes, each 3 changes from the middle to either left or right and reverse and each 3 lane changes directly from the right lane to the left lane and reverse. Mattes [35], as well as Schwalm, Keinath and Zimmer [40] have established in their studies that the Lane Change Task is sensible to cognitive distractions and an easy-to-use tool to get a first impression on the distraction from secondary and tertiary tasks while driving.

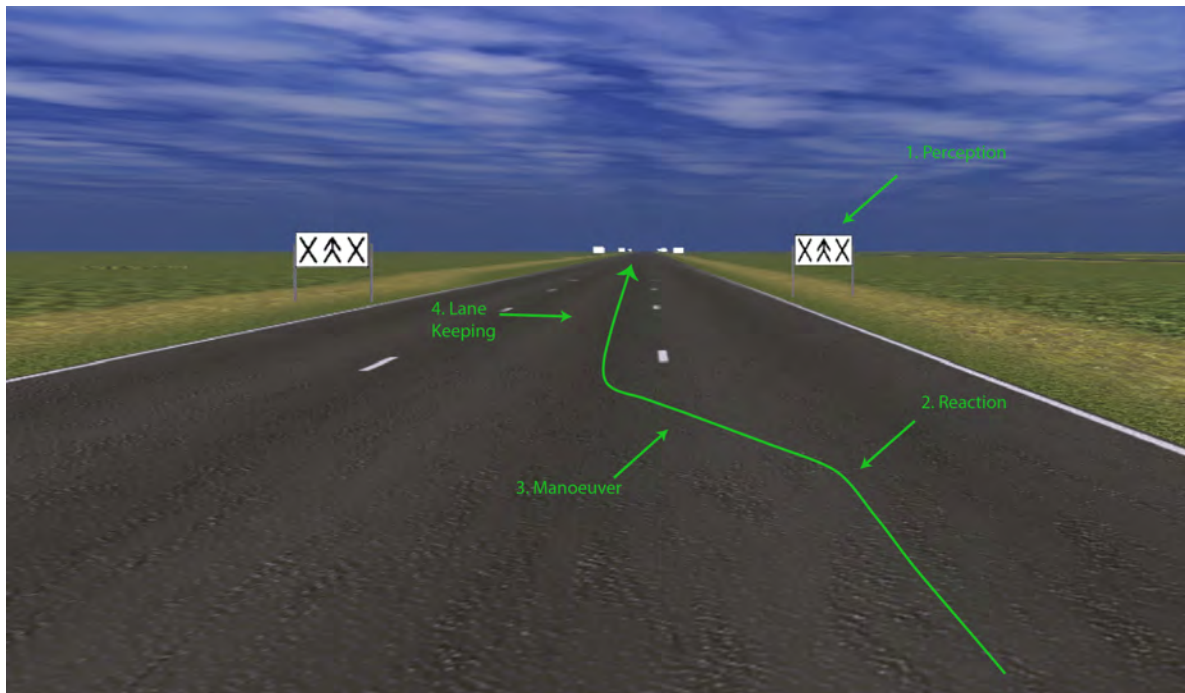


Figure 5.4.: Screenshot of the LCT driving task. Steps by the driver are 1. perception of the requested lane 2. reaction and start of 3. manoeuvre to change the lane with 4. keeping the lane

5.3.2. Implementation of Quiz Mode during Driving Task

After the ground truth lap which is used as a baseline value of the normal driving behaviour without distraction, the participants are asked to repeat the lap in the LCT simulation. Parallel to the driving task which remained the same, the participants need to perform additional operating tasks. The operation of the input elements in the tasks is limited to functions which can be traced by the CAN bus of the modified simulator vehicle. The operating tasks concentrate on the input elements on the multi-function steering wheel, the ACC and the control element for the iDrive menu. The tasks are presented to the participants via the electronic instrument cluster display that was also implemented for the experiment. The electronic instrument cluster as seen in Figure 5.5 displays both speed and rpm, as well as the control of the volume and audio system. The operating tasks are triggered by reaching a specific distance on the track and are the same for all participants and are displayed on the electronic instrument cluster, when the trigger is activated. The display of the task is cancelled if either the right input element is being operated or the duration of the task exceeded.

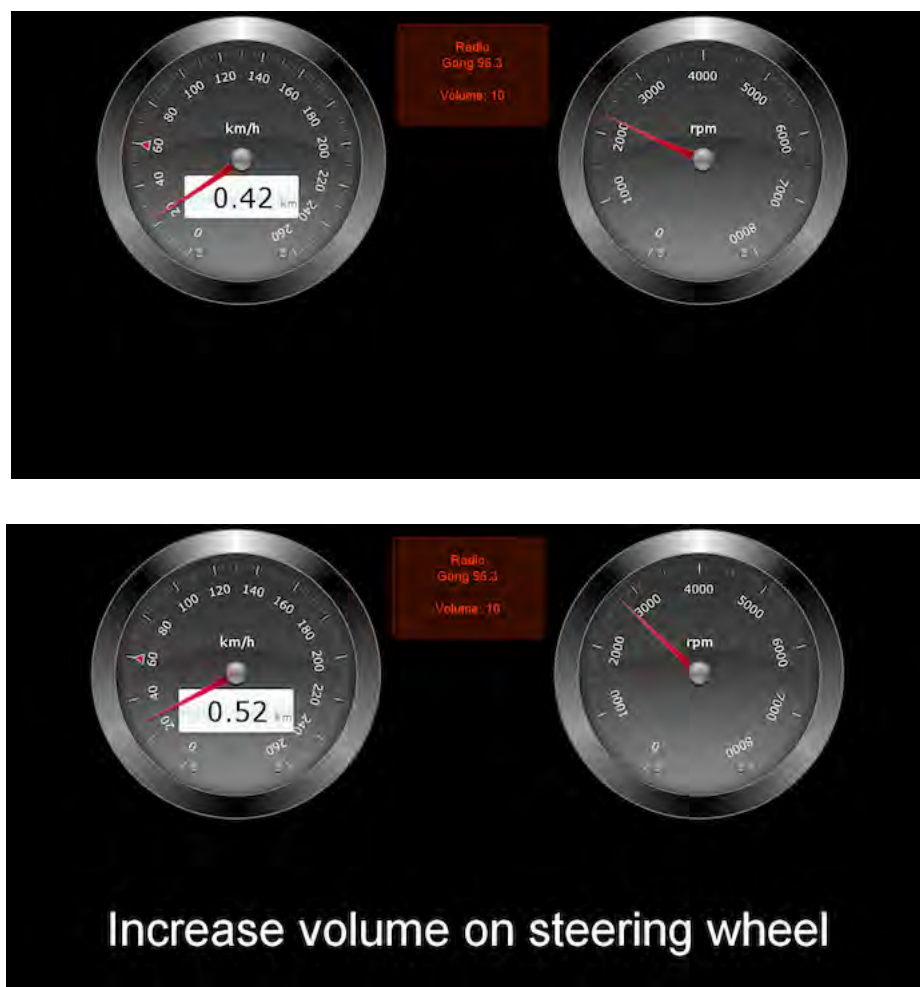


Figure 5.5.: Display of the electronic instrument cluster with implemented speed, rpm, and audio system visualisation. Additional display of operation tasks in experiment round (bottom)

Table 5.1 shows the list of the operating tasks with the trigger distance for the start of the task. The duration of the task is also defined by distance. As the speed is kept at 60 km/h, the duration of the tasks are identical for all participants. The first two tasks only involve the input elements on the steering wheel and are relatively simple for the participant to get familiar to the experiment. The third task involves the iDrive menu and provides a high level of visual distraction to the participant. The fourth task is to activate the ACC and requires more extensive knowledge of the vehicle's interior. The final task once again is solved by interacting with the iDrive menu and requires knowledge of the setup of the menu. The experiment allows testing the distraction from visual input and shows if the experiment group has a higher proficiency in operating the functions of the vehicle after the use of the mobile application compared to the control group.

Begin	Task	Duration
400m	Increase the volume on the steering wheel	200m
800m	Change the radio station via the steering wheel	200m
1200m	Play CD: Sheryl Crow	600m
2000m	Activate the Active Cruise Control	400m
2600m	Start Navigation to 'Home'	700m

Table 5.1.: List of the operating tasks with begin and duration

We implemented the iDrive menu as similar to the original version as possible. The browsing of the menu via the control element in the centre console is given, the menu includes the top level as seen in the top half of Figure 5.6, the first and second sub level. The depth of the menu was chosen to set the visual distraction for the participant to a challenging but not overcomplicated level. The electronic instrument cluster gives visual feedback on the elements of the audio system within the menu, i.e. selecting a CD or changing a radio station. All inputs made in the iDrive menu are only virtual and have no real effects on the simulator.

The iDrive display also acts as the score page when the experiment lap is finished. We included a score for each operating task to emulate the challenge of the Gamification. In contrast to the quiz in the mobile version, no negative score is given for an incorrect answer to prevent additional visual distraction from the road. The completion of each task gives a base score, an additional time score is calculated by multiplying the remaining distance of each task with a factor. The score page on the control display shows the cumulated score after the end of the first experiment lap as seen in the bottom half of Figure 5.6. The participants then get an explanation as to how they can improve their score and are asked to retake the course for a higher score. We increase the motivation to participate in an additional round by telling the participants that the final score is taken for a leaderboard where their results will be compared with others. This additional lap monitors if the participants concentrate more on reaching a higher score than driving safely.

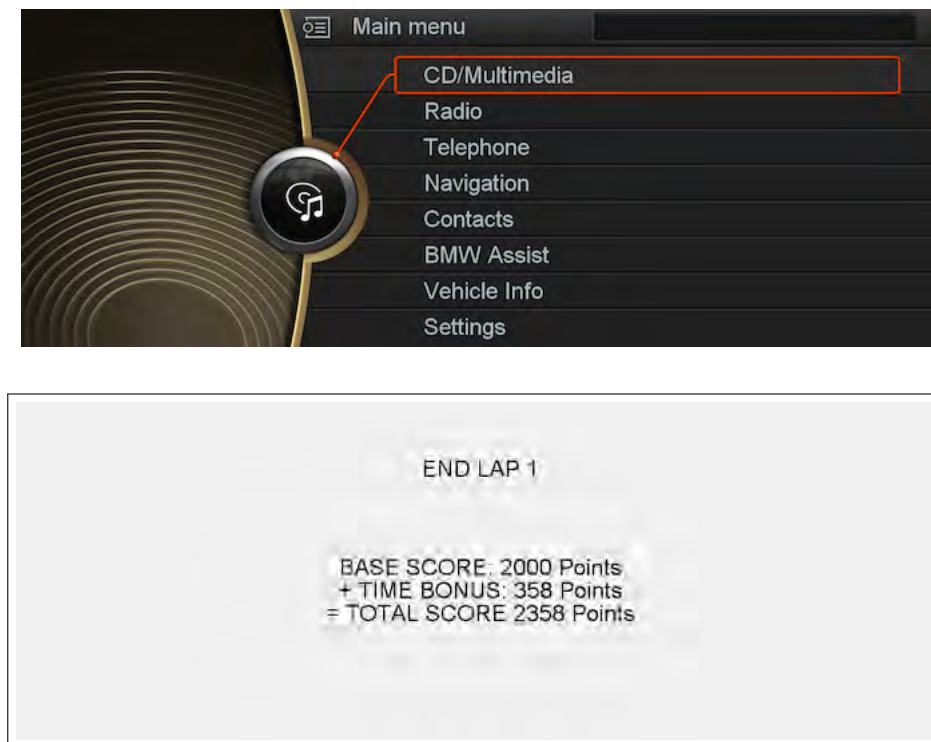


Figure 5.6.: Top: Display of the iDrive menu. Bottom: Display after the end of the experiment lap shown on the iDrive control display.

5.3.3. Data Monitoring & Collection

The experiment conductor can monitor the progress of the participant on the additional monitor of the experiment PC during the experiment. The control window as seen in Figure 5.7 provides the conductor with information on the experiment. After entering an experiment ID for the participant, the conductor can choose from a list of laps. The lap 0 is an introduction round during which the participant gets familiar with the driving physics of the simulator and the rules of the LCT. The lap 1 is the ground truth lap during which the participant establishes their regular driving behaviour. The laps 2 and 3 include the operating tasks that are also shown in the control window. The lap 2 has a lower multiplication factor for the time bonus to artificially lower the score of the participant. This is done to increase the motivation to reach a higher score during the lap 3. Between each lap, the logging needs to be stopped for the data of the lap to be recorded.

During laps 2 and 3, the control window provides information on whether each operating task has been initiated in the 'shown' column. The conductor can compare the total distance above the task window with the task list. The 'solved' column shows whether the participant is able to solve the task, the 'over' column sets the value true when the task is over. The 'solved' value is only set to true when the task is solved, the 'over' value is generally set to true when either the task

is solved or the distance for the task solving has been exceeded. In the lower part of the control window, the iDrive serial communication and the CAN communication of the vehicle is shown so the conductor can assess how proficient and directly the participant is solving a task. All input from the vehicle is saved in a CSV file after the logging is stopped so latter analysis on the task completion and the operating of the input elements is possible.

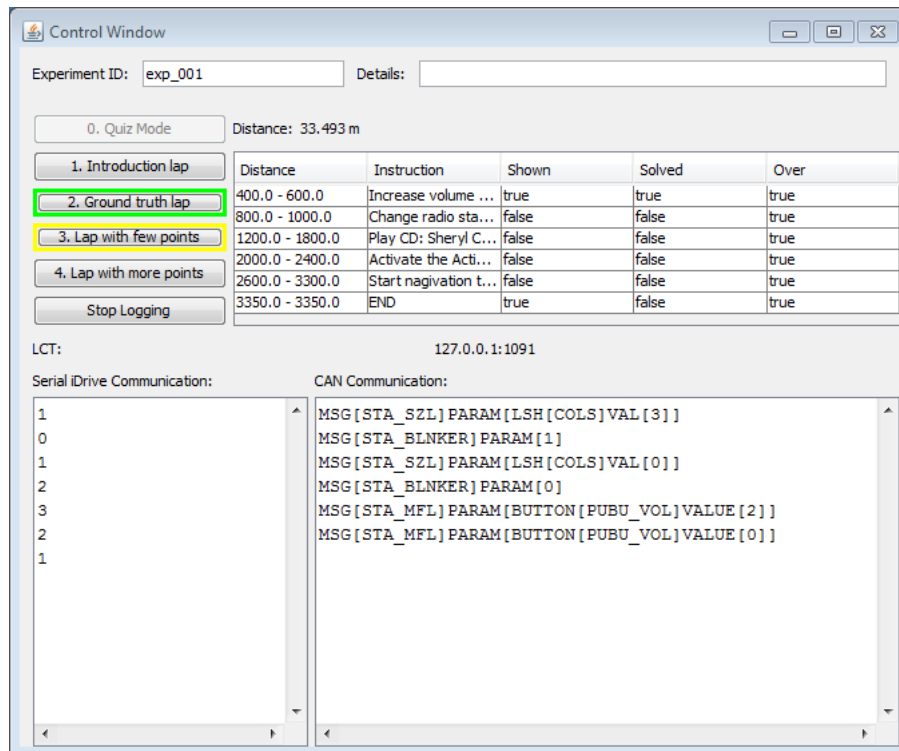


Figure 5.7.: Display of the control window for the conductor to monitor the progress of the experiment. Data shown is: participant ID, lap, list of operating tasks, communication of iDrive and CAN from vehicle.

Additionally to the logging of the vehicle communication, the LCT provides a log of the movement of the vehicle. Figure 5.8 shows a visual representation of the the log provided by the LCT. The green line indicates the ideal track given by the analysis program of the LCT, the red line shows the actual movement of the vehicle. Additionally, the LCT analysis program provides the calculation of the mean deviation from the ideal track that is used as an indicator for the distraction of the operating tasks.

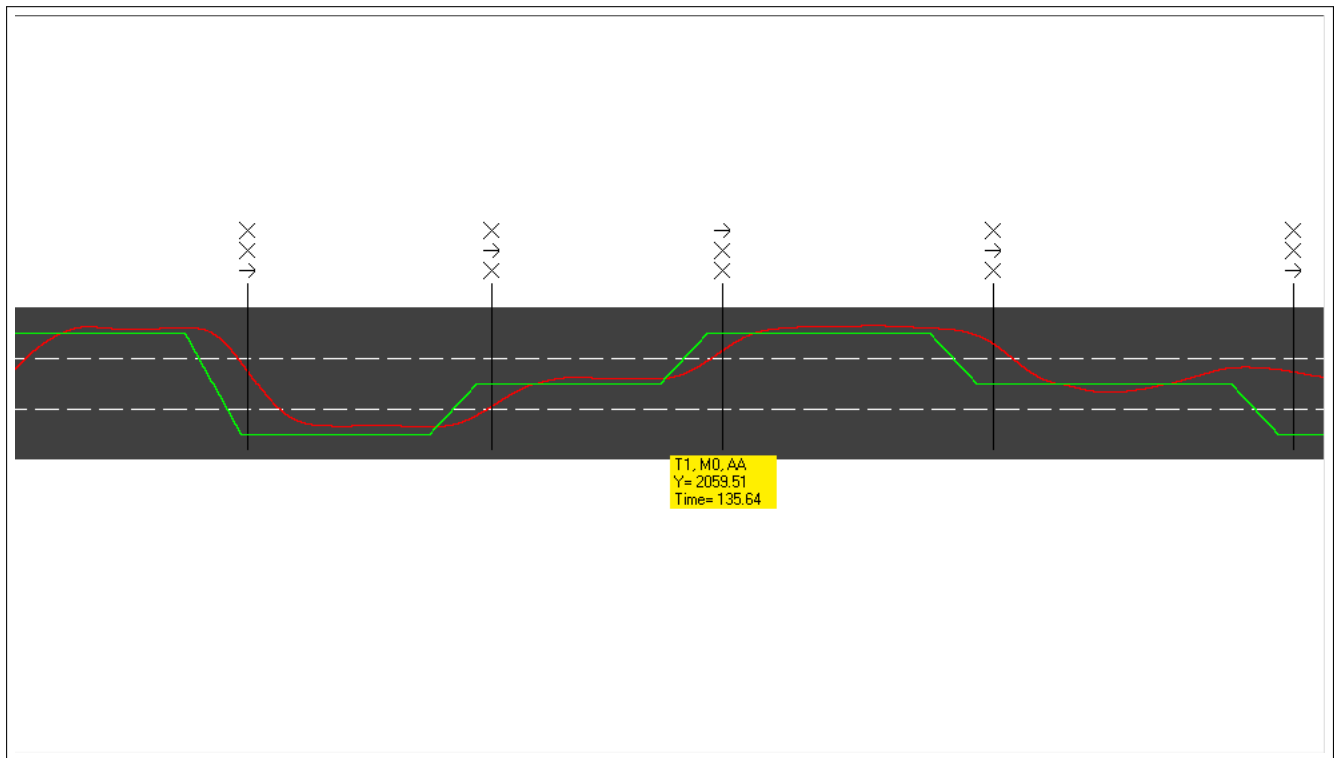


Figure 5.8.: Visual representation of the LCT log on the movement of the vehicle during the lap.
Green line indicates the ideal track, red line shows the actual track.

Chapter 6.

Evaluation of the Experiment and Improvement Ideas

6.1. Pre-Experiment Questionnaire

The participants were asked to fill out part of the questionnaire before the experiment for further assessment of their driving behaviour and their interaction with technical equipment. These are the results.

The experiment consisted of 30 participants, 5 females and 25 male, the age ranging from 19-28 years (Median $\mu_{(1/2)} = 25$ years, Standard Deviation $\sigma = 2.53$ years) and a mean driving experience of 6 years ($\sigma = 2.53$ years). The participants of the control group have an average age of 24.5 years ($\sigma = 2$ years) and an average driving experience of 6.8 years ($\sigma = 2.14$ years), the participants of the experiment group have an average age of 23.2 years ($\sigma = 2.91$ years) and an average driving experience of 5.13 years ($\sigma = 2.67$ years) (Figure 6.1. To determine if the difference in driving experience between the groups is statistically significant, we apply the formula for the t-value

$$t = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

and get $t = 1.89$ for the driving experience ($\mu_1 = 6.8$, $\mu_2 = 5.13$, $\sigma_1 = 2.14$, $\sigma_2 = 2.67$, $n_1 = n_2 = 15$). We look up the table for significance. For a two-tails test and $df = n_1 + n_2 - 2 = 28$ degrees of freedom, $\alpha = 0.1$, i.e. the difference is statistically significant for a 90 % confidence. In general, a confidence level of at least 95 % ($\alpha = 0.05$) is asked for statistical significance. We thus dismiss the difference in driving experience to be of significance.

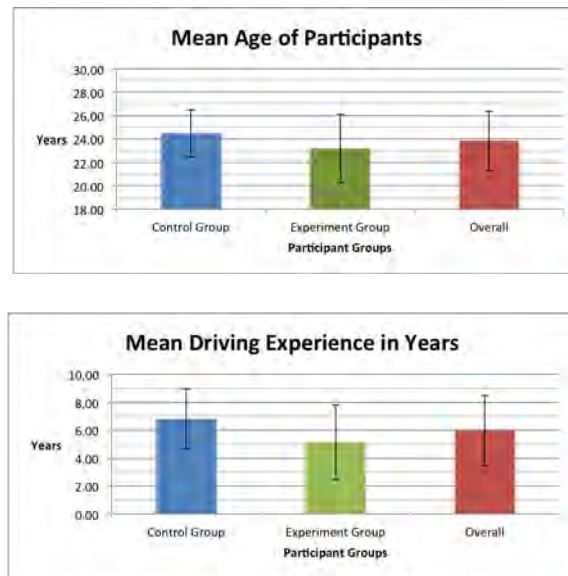


Figure 6.1.: Participants' Age (Top) and Driving Experience in Years.

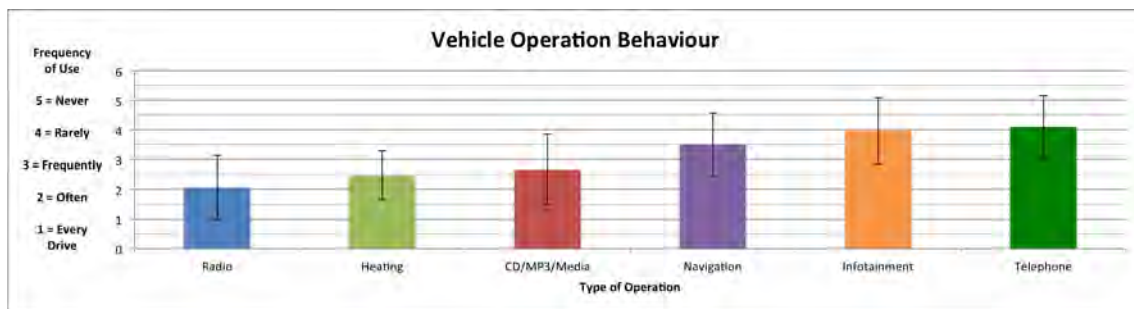


Figure 6.2.: Vehicle Operating Behaviour of Participants. Mean Values and Standard Deviation of all Participants

In-Car operating behaviour

The most common operations our participants make in the vehicle are connected with radio functions as well as own music media as seen in Figure 6.2. Almost half of the participants use the radio system in every journey, another third uses it often or frequently. The heating system is most used next after the audio system with evenly spread results in use. The participants state to frequently use a navigation system, the infotainment system and the telephone are rarely used.

Use of Technical Devices

The results in Figure 6.3 show that the participants are mainly using smartphones (Mean $\mu = 1.33$, S.D. $\sigma = 1.28$; 1 = Use more than once a day, 2 = Daily, 3 = More than once a week, 4

= More than once a month, 5 = Participant does not own device) and personal computers ($\mu = 1.17$, $\sigma = 0.38$). Only a third of the participants owns a tablet device ($\mu = 3.7$, $\sigma = 1.73$).

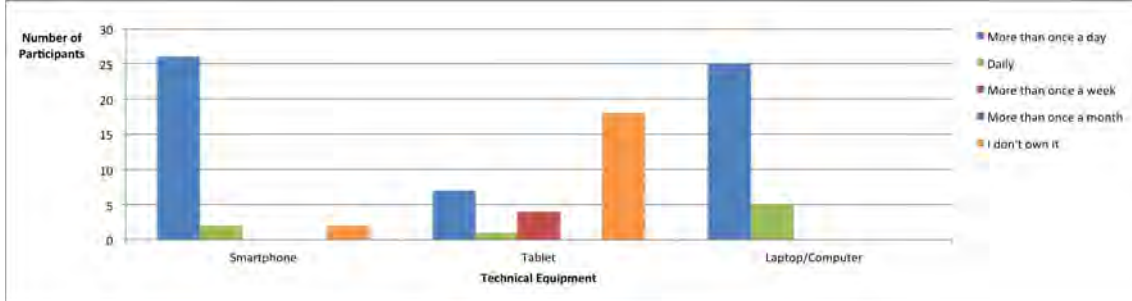


Figure 6.3.: Use of Technical Devices. x-scale: frequency of use, y-scale: number of participants, for smartphone, tablet device, and computer

We additionally asked the participants which functions of their smartphone they use and how often. The results show that the most common function of the smartphone is for written communication, i.e. instant messaging and e-mails ($\mu = 1.33$, $\sigma = 1.03$; 1 = Use more than once a day, 2 = Daily, 3 = More than once a week, 4 = Less than once a week, 5 = Less than once a month). Almost all participants use this function of their device more than once a day. Less than half that many use the phone for actual calling ($\mu = 1.97$, $\sigma = 1.00$). This result shows that modern communication relies more written messages thanks to the constant Internet connectivity and virtual keyboard of the touchscreen. The Internet connectivity is also frequently used by two thirds of the participants for web browsing ($\mu = 1.87$, $\sigma = 1.28$). When asked what the web browsing includes, a great number of the participants stated that they mostly use the Internet for reading news or finding information quickly. Other often used functions are business ($\mu = 2.17$, $\sigma = 1.39$) and social networks ($\mu = 2.33$, $\sigma = 1.42$) applications. We categorized business applications as all applications that increase productivity, help organisation or provide information. Only a low number of participants stated that they use their smartphone regularly for games ($\mu = 4.00$, $\sigma = 1.44$). In total, the results show that the main use of the smartphone is for written communication and keeping contact with other people. The demand for informative and productivity applications is one of the second most popular functions for users in the participants' range of age. We examined the correlation between age and use of games and respectively business applications to see if younger participants preferred games to business applications and vice versa for older participants. For the correlation

$$\rho_{X,Y} = \text{corr}(X,Y) = \frac{\text{cov}(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X - \mu_X)(Y - \mu_Y)]}{\sigma_X \sigma_Y}$$

the result for the correlation between age and use of business applications was $\rho_{\text{Age}, \text{Business}} = 0.04$ and the correlation between age and games was $\rho_{\text{Age}, \text{Games}} = 0.05$ which indicates that the use of either category of application was not dependant on the age in our participant group.

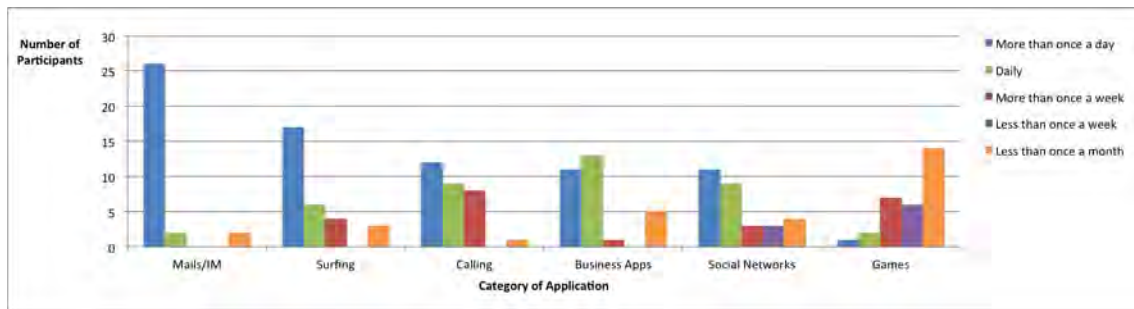


Figure 6.4.: Use of Smartphone/Tablet according to functions and frequency. x-scale: frequency, y-scale: number of participants

Participants' Self-Assessment

The final part of the pre-experiment questionnaire asked the participants to give a short self-assessment of themselves (Figure 6.5). This includes the technical interest, the attitude towards documentation, and their competitiveness. For the technical interest, we asked for their general interest in technology which almost all participants agreed to either strongly or otherwise ($\mu = 1.60$, $\sigma = 0.77$; 1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree). This result correlates with the fact that a high number of participants were students of the electrical engineering faculty. A further question asked about their technical interest is whether they would spend a bigger amount of time to solve a problem. The ambition to spend time on problem solving is slightly smaller than the actual interest in technology ($\mu = 1.73$, $\sigma = 0.78$). The ambition to understand the underlying functionality is yet again lower but still positive ($\mu = 1.77$, $\sigma = 0.68$). As we have established earlier and as the results for the consultation of documentation shows, only a fraction of the participants agrees that they would read the manual to understand a product or solve a problem. Most participants are indifferent to the user manual, an equally high number states that they would not read a manual ($\mu = 3.43$, $\sigma = 0.77$). On the question whether they were competitive in games and sports, most participants stated that they were competitive to a certain degree ($\mu = 1.90$, $\sigma = 0.92$).

These results show that our application should address the interest in technology and explain how the functions of the vehicle user interface work. It should act like a manual, but not convey the character of a documentation too strongly. The competition in the quiz acts as a good motivator as most people see themselves competitive and have the ambition to score better than others.

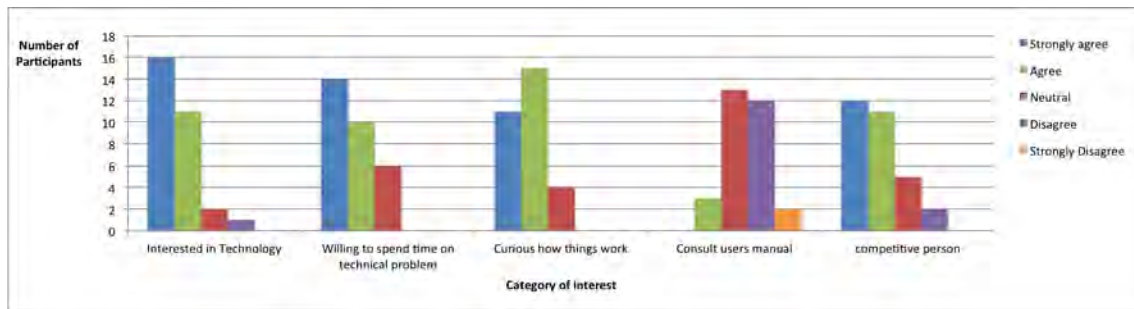


Figure 6.5.: Self-Assessment of Participants' behaviour concerning technology, and their competitiveness. x-scale: level of agreement towards the question, y-scale: number of participants

6.2. Assessment of Mental Workload during Experiment

After each round of the experiment, we asked the participants to fill out the NASA-TLX to assess the workload. Figure 6.6 shows the average of all participants' evaluations of their mental workload for the three laps. The participants were asked to mark any box they felt represented their assessment best on the NASA-TLX as seen in Appendix B. The scale ranges from 0 representing 'very low' to 20 representing 'very high'. The results show that the participants feel that the first experiment lap has a much higher mental demand than the ground truth without operating tasks. The mental stress slightly decreases in the second experiment lap as the participants got used to the nature of the operating tasks. In direct correlation to the mental demand is how they perceived the pace of the tasks and their insecurity level. Apart from the mental stress, the participants also describe that the physical demands increase. Some participants stated in the interview afterwards that the physical stress they felt was not merely due to the additional operating tasks but was also the result of the mental stress.

The participants all assessed their level of success highly in the ground truth. In the first experiment lap, the level of success strongly decreased and increased again in the second experiment lap. When we compare the assessment to the results of their mean deviation from the LCT analysis and from the answers given in the interviews, the success rate that they assessed was based on the completion of the operating tasks and not on their driving safety.

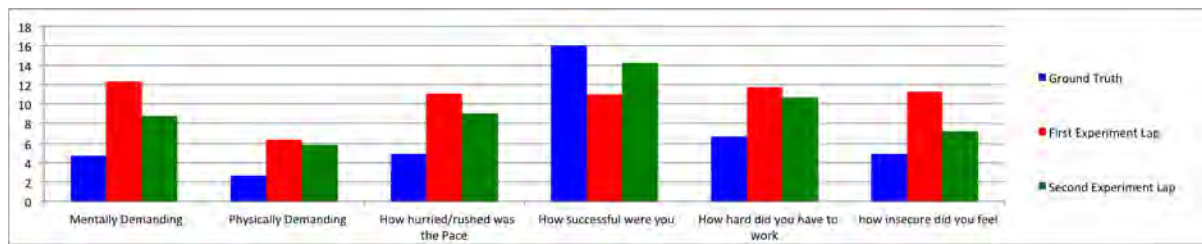


Figure 6.6.: Assessment of the mental workload with the NASA-TLX after ground truth, first and second experiment lap. x-scale: categories of NASA-TLX, y-scale: average value given by all participants

6.3. Post-Experiment Questionnaire

After the experiment, the participants were asked to fill out the remaining part of the questionnaire that included the evaluation on the experiment itself and the mobile application for the group that used it.

Evaluation of the Experiment

We asked the participants specific questions on the driving and operating tasks to assess whether the use of the mobile application would have an effect on the perception of these tasks. Figure 6.7 shows the results of the questions. Table 6.1 shows the results of the t-Test performed on the evaluation of the test by the control group and experiment group. For a two-tails test with $df = 28$ and $\alpha = 0.05$, a t-value higher than 2.048 or lower than -2.048 is needed to show significant difference between the results of the two groups. None of the t-values of any category exceeds this value. The perception of the test by both experiment group and control group is thus not significantly different.

Evaluation Question	Control Group		Experiment Group		t-Test
	μ_c	σ_c	μ_e	σ_e	t
Tasks were too difficult	3.93	0.59	4.13	0.74	-0.30
Tasks represented my driving style well	3.07	1.10	2.53	0.92	0.53
Goal was to drive safely	2.73	1.03	2.33	0.98	0.40
Goal was to accomplish tasks quickly	1.67	0.62	1.73	0.70	-0.10
Goal was to reach a high score	1.93	1.03	1.80	0.77	0.15
Test felt more like a game	2.53	0.92	2.67	1.05	-0.14

Table 6.1.: Mean and Standard Deviation of Control Group and Experiment Group on the Evaluation Questions about the Driving Test. t-Test Value for Test of Significance.

Both groups state that the tasks were difficult, but manageable. In general, the participants felt rather neutral towards the question whether the tasks represented their own driving style. Most stated that they would not operate any functions in the car while changing lanes. Also, most participants were not familiar with the ACC or did not know the iDrive menu. Most stated that their goal was to drive safely. However, a higher number of participants was more focused on accomplishing the operating tasks quickly than on driving safely. A similarly high number of participants also stated that they were inclined to reach a higher score. The high competitiveness to reach a better score shows the negative effects on driving safety from Gamification. Including competition elements in a vital situation such as driving takes the main focus and attention of manoeuvring the vehicle to participating in a challenge. Finally, we analysed if the whole experiment setup felt more like a game than a real life situation. Our intention was to create a surrounding that was as realistic as possible by using a real BMW model simulator and implementing the electronic instrument cluster and iDrive menu close to the original. However, the results show a rather mixed opinion of the participants whether the simulation felt like a real life situation. The most common reasons given why it did not feel like a real situation were that the driving physics of the simulator were unrealistic. Due to the fact that the interior of the simulator looks very real, the participants expected haptic feedback while manoeuvring the vehicle. Additionally, the steering was too sensitive which made it hard to keep accurate control of the vehicle. Furthermore, the track itself was evaluated to be unrealistic. The participants stated that they would not drive such a long straight track, that the traffic was missing, and that they would not change lanes as often as they did during the experiment.

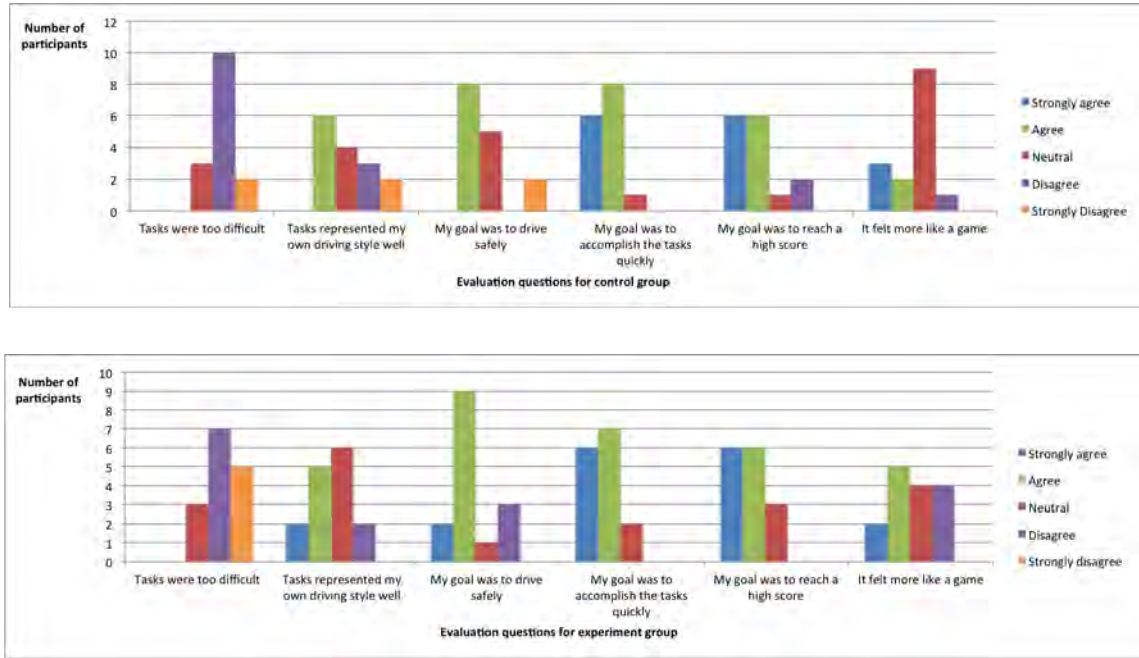


Figure 6.7.: Evaluation of driving task (top: control group, bottom: application group). x-scale: level of agreement towards the question, y-scale: number of participants

We take a look at the results of the LCT analysis for quantitative values of the participants' performance. From the LCT analysis, we get a mean value for the absolute deviation of each round. The analysis software takes the set $\{x_1, x_2, \dots, x_n\}$ with x_i representing x-position of vehicle on the ideal track at the timestamp i and the set $\{d_1, d_2, \dots, d_n\}$ with d_i representing the actual x-position of the vehicle and calculates the mean deviation

$$D = \frac{1}{n} \sum_{i=1}^n |x_i - d_i|$$

over the entire lap. We use the deviation D as an indicator for the level of distraction that the participant experiences. We do not compare the deviations of different participants with each other, but the change in deviation of each user between the different laps. Figure 6.8 shows the deviation as a percentage value compared to the ground truth lap. Each double column represents one participant, the first column marks the difference between the ground truth and the first experiment lap, the second column marks the difference between the ground truth and the second lap. A value of 100 % means the same deviation on either experiment lap compared to the ground truth, a lower value means that the participant performed better at driving safely while a higher value indicates that the participant did worse and was therefore more distracted. The order of participants is aligned from lowest increase in deviation to highest increase in deviation between the ground truth and the first experiment lap from left to right and is not a representation of the actual order of the participants. It is clearly observable that almost all participants had a

higher level of distraction during the first experiment lap. The comparison between the first and second experiment lap is more ambiguous as 10 participants have an increase in deviation while the rest managed to decrease their deviation compared to the first experiment lap. A third of the participants managed to reach a value that is similar or lower than the deviation of the ground truth. As the operating tasks did not change between the first and second experiment lap, these results would indicate that the practice and gained knowledge from the first experiment lap has a higher impact on the performance than the distraction from the competition.

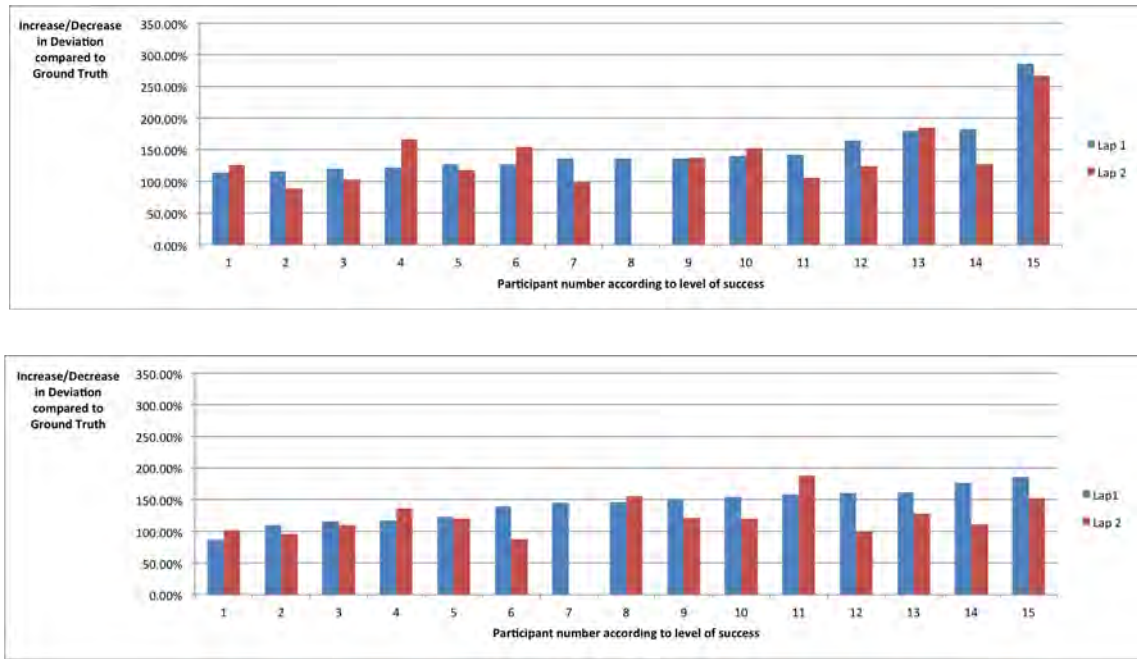


Figure 6.8.: Individual increase in mean deviation between ground truth and experiment laps 1 and 2. x-scale: participant number, y-scale: percentage of deviation compared to ground truth.(top: control group, bottom: experiment group)

To find differences between the groups, we compare the results of the groups in general and analyse individual results of more striking cases. For the values of the groups, we take the harmonic mean

$$H = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \dots + \frac{1}{x_n}} = \frac{n}{\sum_{i=1}^n \frac{1}{x_i}}$$

of all the values in each group. Due to the high dispersion of the results between the participants, we decided on the harmonic mean as opposite to the arithmetic mean to get the most representable average. With this calculation, we get the result that the participants of the control group had an average driving experience of 6.8 years ($\sigma = 2.14$ years) while the participants of the experiment group had an average driving experience of 5.1 years ($\sigma = 2.70$ years). The experiment group had a slightly better performance with a value of 136.8% of deviation in the first experiment lap

compared to the ground truth and 118.9% of deviation in the second experiment lap. The control group's values are 141.1% of deviation in the first experiment lap and 129.4% of deviation in the second experiment lap. The results from both groups confirm that the driving safety increased from the first to the second experiment lap despite the additional competition from the score. The t-value between the control group and experiment group for the first experiment lap is $t_{L1} = 0.51$ and $t_{L2} = 1.18$. With a two-tailed test, $df = 28$, $\alpha = 0.05$, neither value exceeds the threshold for significance of 2.048. There is no significant difference between the results of the experiment group and control group. We further examined the correlation between the driving experience of the participants and their deviation from the ideal track. For the control group, the value is $\rho_C = -0.43$, for the experiment group, the value is $\rho_E = 0.21$. This result indicates that in the control group, the driving experience has a small significance on the performance. In the experiment group, the driving experience was not a significant factor.

We take a look at the completion of the operating tasks next. Table 6.2 shows the number of participants that managed to accomplish the operating tasks from each group. The values are for the first experiment lap before the front slash and for the second experiment lap after the front slash. In each group, one participant did not participate in the second experiment lap (lap 1: $n = 15$, lap 2: $n = 14$).

Task	Control Group		Experiment Group	
	max 15	max 14	max 15	max 14
Task 1: Increase the volume on the steering wheel	14	14	14	14
Task 2: Change the radio station via the steering wheel	12	11	11	11
Task 3: Play CD: Sheryl Crow	12	14	11	13
Task 4: Activate the Active Cruise Control	5	5	9	10
Task 5: Start Navigation to 'Home'	11	14	10	11

Table 6.2.: Accomplishment of operating tasks. Number of participants that accomplished the task for first experiment lap/second experiment lap. 15 participants in each group during first experiment lap, 14 participants in each group during second experiment lap.

During the first experiment lap when the tasks were unknown, we see no significant differences between the groups except for the task 4. Almost twice as many participants of the experiment group were able to activate the ACC compared to the control group. This indicates that the mobile application is helpful for functions that are not plainly visible to the driver, or more advanced functions that are not commonly used. The results of the second experiment lap show that the

participants of the control group had a higher motivation in finding all functions and accomplishing the tasks while the experiment group remained rather constant compared to the first lap. The implication of this result is that the participants who did not use the mobile application were more inclined to use a 'learning-by-doing' method. The participants that used the mobile application relied on the fact that they forgot the information from the application and were not inclined to try blindly. This result is confirmed by the number of input actions. The control group had an average of 12% more input actions during the second lap compared to the first lap while the experiment group only had an increase of 6%.

Lastly, we take a look at individual results of the experiment. We combined the increase in deviation and the score of the participants to compile a leaderboard. The reason to use this kind of score was to reward not only the accomplishment of the operating tasks, but also driving safely. We will analyse the three best and worst results. The best score was by a participant of the control group. The participant had the highest driving experience with 11 years and has stated to have worked as a driver for BMW. This is a clear support of our earlier proposal that driving experience is a great factor for safe vehicle handling. The participants with the second and third highest score however, only have 3 and respectively 2 years of driving experience. Both participants were in the experiment group and used the mobile application before the experiment. In comparison, the only participants of the control group with a similarly low level of driving experience placed last and fourth to last. This result indicates that the mobile application can compensate for a lack of driving experience to a certain extend.

The second and third to last positions in the leaderboard were also participants of the experiment group. We analysed their answers on the questionnaire and collected additional feedback in the interview to assess why the mobile application did not help them achieve a better result. The second to last participant had 3 years of driving experience and already stated in the pre-experiment questionnaire that she felt rather neutral about their technical interest and her ambition to invest time in solving technical problems. Although she stated that the mobile application was both fun and useful, the main critic was that it was not connected enough to the reality. After the virtual representation of the vehicle user interface, a tutorial in the real vehicle would have been necessary. Additionally, the participant stated that she did not invest enough time and effort into familiarising themselves with the mobile application. The third to last participant gave a similar feedback. Although he had 7 years of driving experience and stated in the questionnaire that he was very interested in technology, the main problem was that he did not pay attention to the descriptions of the functions in the mobile application, but wanted to finish the exploration mode as quickly as possible.

Evaluation of the Mobile Application

Figure 6.9 shows the results of the group of 15 people that used the application prior to the driving tasks. As we can see, the application was mostly received positively. The users assessed the application to be both fun ($\mu = 1.80$, $\sigma = 0.56$; 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree) and useful ($\mu = 1.73$, $\sigma = 0.46$). The participants were asked in the feedback if they would put the application in a game or information category. They answered that it was neither and both, with the cockpit view and the function list being more informative and the quiz mode including a game-like feeling. This feedback proves that we have succeeded in creating a gamified system.

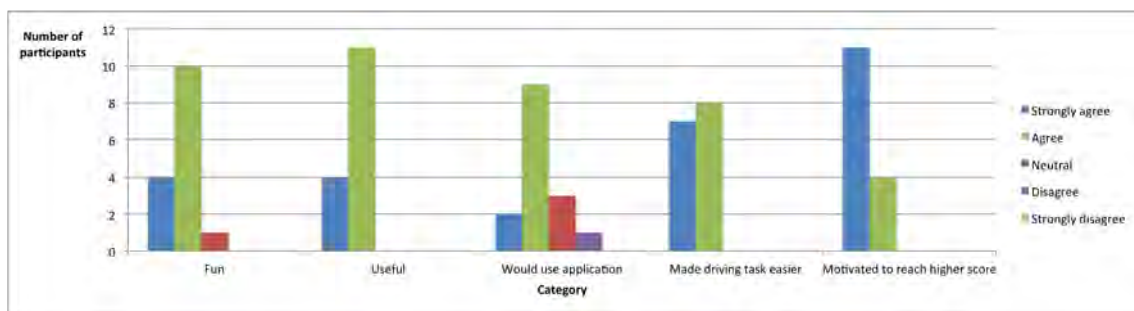


Figure 6.9.: Evaluation of the Mobile Application

When asked if they would use the application in a real situation, a dominant part said yes ($\mu = 2.20$, $\sigma = 0.77$). However, a few stated that they would still prefer the trial-and-error method to learn and that the connection to the car was not strong enough. We have stated in our hypothesis earlier that trial-and-error in a moving vehicle will pose unforeseeable safety risks. People that are used to operating on this method need to be sensitised into changing their behaviour by the application.

Extending the quiz mode can prove successful in further trials as it was well received in the experiment. After completing the cockpit mode and finding all functions, the participants were given time to try out the quiz mode. They were being told that they could try it until they got bored of it and the majority of participants took several runs at the quiz mode. This is also reflected in the questionnaire's results. Almost all participants state that they strongly agree to being motivated to improve their initial score ($\mu = 1.27$, $\sigma = 0.46$). The challenge to beat the own score results from the ego enhancement that was mentioned in the OIT. According to the participants' perception, the application was also helpful for the operating tasks during the simulator test ($\mu = 1.53$, $\sigma = 0.52$).

6.4. Participants' Feedback and Improvement Ideas for the Application

We have established that the mobile application was received predominantly positive and that it can compensate a lack of driving experience and knowledge of the vehicle user interface if the investment into the application is high enough. We include in this part the feedback that was given in free form of the questionnaire as well as the direct feedback from the interviews.

Visual Improvements

Although we used a high definition image, feedbacks were given on the fact that the resolution was too low when the image was zoomed in. Additionally, we tested the mobile application on a Nexus 7 tablet device with a 7 inch screen (17.78 cm diagonal). According to the questionnaire however, a high number of people do not own a tablet and therefore, the application must be revised for smaller screens. Since the vehicle user interface has a high number of input elements, accommodating the whole interior in one image is not advisable. One possibility to change the visual setup of the application is to split up the areas of the vehicle user interface similar to BMW's driver manual for Android devices¹ as seen in Figure 6.10. The different areas can then be used in a story mode or in different levels in addition to the view of the complete vehicle user interface.

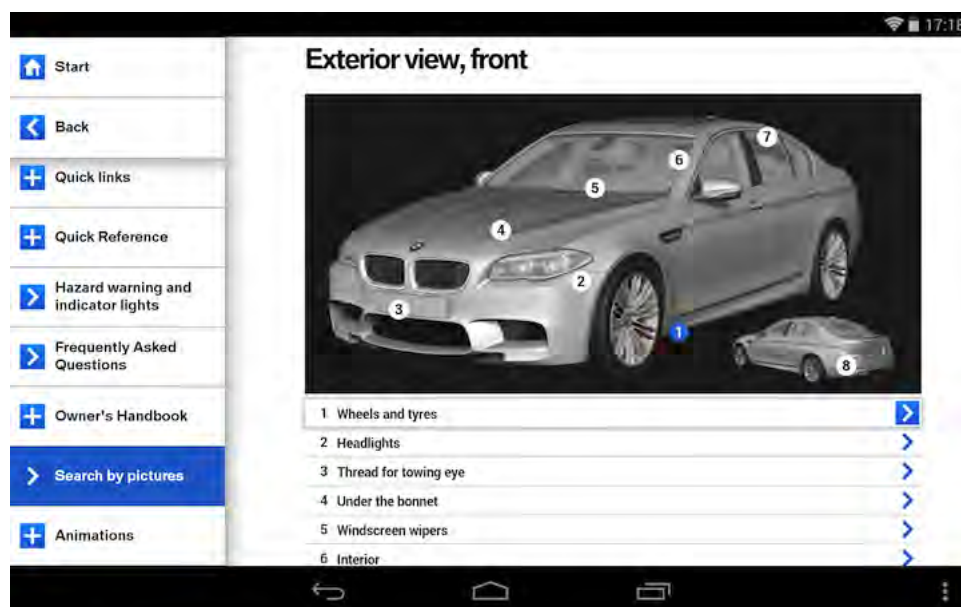


Figure 6.10.: Example of the BMW Driver's Guide for Android. A digital version of the user manual.

¹ <http://goo.gl/6WNIW>

Underlying Non-Game Context

The implementation of smaller areas can also benefit to increase the importance of the underlying non-game context. The feedback stated that not a lot of time was invested to read the information on the input elements but the goal was rather to find them all in a short amount of time. A different feedback stated that the amount of information was too much and it was therefore difficult to remember everything. The division into smaller areas would help the user structure the input elements and connect them to a subgroup of the same functionality class. A free exploration mode however is too chaotic for novice users.

An important improvement that needs to be included is to put more emphasis on the information on the functions and the operation of the input elements. More visual and audio output can make the information more appealing than written text. One feedback suggested to implement a function where the application reads the information to the user. Including sprites that show how the input element is operated can also make the user memorise the element easier.

Connectivity to the car

Many participants missed the connection of the mobile application to the reality. They stated that an online tutorial or quiz mode inside the vehicle would have a much higher learning effect than the offline quiz. One way is to read out the data from the K-CAN as is done in the simulator by using an on-board diagnostics II (OBD-II) scanner². The scanners can be purchased at a low price and provide bluetooth connectivity with a mobile device. This can also support the proposed background and preset modes of our concept. Future studies need to determine if the low price devices can acquire the necessary data from the CAN bus. Another option is to use an augmented reality system such as Audi's *eKurzinfo*³ mobile application that presents the user with information of a function when the user selects the respective input element with the mobile device's camera as seen in Figure 6.11.

²goo.gl/e2e1Nc

³Audi eKurzinfo, <http://www.metaio.com/customers/case-studies/audi-ekurzinfo-app/>



Figure 6.11.: Example of Audi's eKurzinfor mobile application. eKurzinfor is an augmented reality application that shows the user information on an input element that is selected with the camera of a mobile device. (<http://goo.gl/pk9j5B>)

Answering the Research Questions

In Section 5.2.2, we posed following research questions:

1. Is the Offline *Quiz Mode* enough to familiarise with the vehicle user interface?
2. Does the offline training in the *Quiz Mode* improve the driving performance of the participants?
3. Do the competition aspects of the Gamification have increasing safety-impairing effects?

From the results of the experiment, the answers are:

It is stated by the participants that the offline *Quiz Mode* is not enough to represent the vehicle user interface. An online tutorial in the car is needed to reach a sufficient level of familiarisation with the user interface.

The participants of the experiment group did not reach a significantly better result during the driving tasks compared to the control group. The use of an *Online Mode* and longer engagement with the application is needed to determine if the application can reach a higher efficiency in training the participants.

The participants based their success in the driving task on their performance on the operating tasks instead of the driving safety. The focus on driving safely is shared with the competition aspects of the Gamification. During the second experiment lap when the competition aspects

were introduced, the driving performance of the participants were higher compared to the first experiment lap when the operating tasks were introduced. The experience of the operating tasks outweighs the competitiveness of the Gamification in the experiment. The safety risks in a real life situation remain unquantified.

Chapter 7.

Conclusion and Future Work

We started this work by analysing the operation behaviour of drivers and determined that many users state that they do not have the knowledge of all existing features of their vehicle. The inhibition towards consulting documentation is given by a lack of time and gamefulness. We examined the most common known problems with unattractive documentation and the theory on how to raise motivation. We introduced Gamification as a practical means to raise motivation and analysed common definitions of Gamification.

From this theoretical knowledge, we developed a concept for a mobile application that implements Gamification elements to attract users into interacting with a virtual documentation. The concept is implemented for Android devices a visual representation of the vehicle's interior where the user can explore the vehicle user interface without risk and test their knowledge with a quiz. We explained the setup for the experiment to test the implemented prototype and analysed the results. The results show a minor difference between a base group and an experiment group that used the mobile application before performing the experiment. The prototype of the proposed application is generally received positively by the participants and shows potential to compensate for a lack of driving experience. In the present stage, the prototype lacks the ability to successfully convey the underlying non-game context of educating the user.

We gave proposals for further development of the application. For a future work, the structure of the concept model should be revised. A more linear mode to initially familiarise with the vehicle user interface is necessary and the amount of information should be divided into smaller packages. The visual setup of the application should be changed to fit smaller mobile devices than the Nexus 7 tablet that was used in the experiment. The participants had a positive attitude towards the implemented Gamification elements that were represented by the quiz mode. A future work could extend the quiz elements with which the user can test themselves and most importantly, the connection between the mobile application and a real vehicle could be implemented. We proposed the connectivity with either an on-board diagnostics device that can be connected with the mobile device via bluetooth or an augmented reality feature. The interactivity of the application can be increased with audio output and more visual media instead of textual information. After

implementing these proposals, a longer study could be conducted to provide a realistic experiment environment and observe the actual effects of the mobile application.

Appendix A.

Pre-Experiment Questionnaire

Participant's questionnaire for Lane Change Simulation

Experiment ID: _____

Age: _____

Gender:

☐ male

☐ female

Group (you don't need to fill this): _____

Driver Experience

How long have you had a driver's permit:

_____ years

What car models have you driven before:

Have you driven the BMW 3/5 series before:

☐ yes

☐ no

If yes, do you have experience with the Adaptive Cruise Control (ACC)?

☐ yes

☐ no

If yes, do you have experience with the iDrive menu?

☐ yes

☐ no

Please select the option that best describes your driving style (only select one option)

- My driving style is

- ☐ very sporty
- ☐ rather sporty
- ☐ rather comfortable
- ☐ very comfortable

How often do you use following functions while driving?

	Every Drive	Often	Frequent-ly	Rarely	Never
1 Radio	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 CD/MP3/Own Media	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 Heating and Cooling Functions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 Infotainment System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 Navigation System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6 Telephone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Technical Experience

Please select the devices that you own and the frequency that you use them:

	More than once a day	daily	More than once a week	More than once a month	I don't own it
1 Smartphone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 Tablet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 Laptop/Computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please specify what you use your smartphone for and how often

	More than once a day	Daily	At least once a Week	Less than once a week	Less than once a month
--	----------------------	-------	----------------------	-----------------------	------------------------

- | | | | | | | |
|---|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | Calling people | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 | Checking mails/instant messages..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 | Surfing the Internet | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4 | Social Networks | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5 | Games | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6 | Business Applications (to-do lists, calendar)..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Select the option that describes you best:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
--	----------------	-------	---------	----------	-------------------

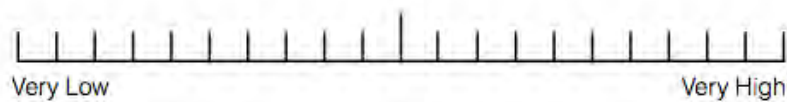
- | | | | | | | |
|---|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | I'm interested in new technology and try to keep up | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 | I'm willing to spend time to figure out a technical problem | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 | I'm always curious in how things work..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4 | I consult the user's manual before using a product..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5 | I'm a competitive person in sports & games..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Appendix B.

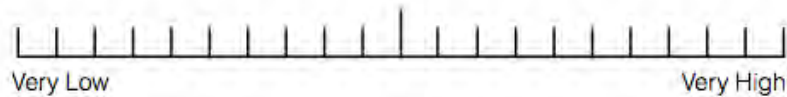
Mental Workload Assessment

Assessment of Lane Change Simulation (Base Line)

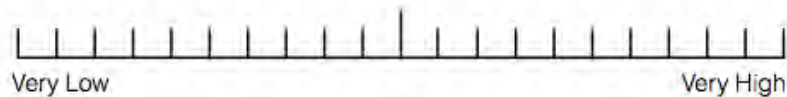
How mentally demanding did you find the task?



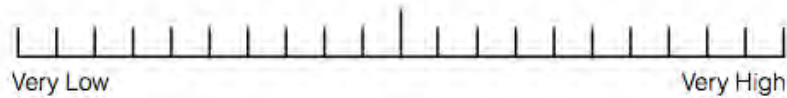
How physically demanding did you find the task?



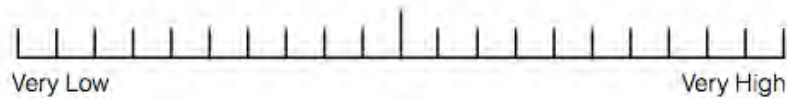
How hurried or rushed was the pace of the task?



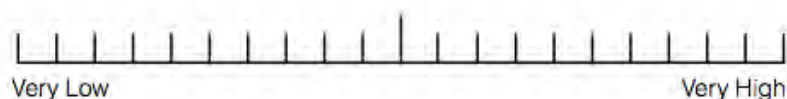
How successful were you in accomplishing what you were asked to do?



How hard did you have to work to accomplish your level of performance?



How insecure, discouraged, irritated, stressed, and annoyed were you?



Appendix C.

Post-Experiment Questionnaire

Evaluation of the Mobile Application

Please evaluate the mobile application:

Strongly
Agree

Agree

Neutral

Disagree

Strongly
Disagree

1	The application was fun	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	The application was useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	I would use such application before buying a car.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	The application made the tasks easier for me.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	I was motivated to reach a good score in the application.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Additional comments for the mobile application:

Evaluation of the Lane Change Task Simulation

Please evaluate the lane change tasks:

Strongly
Agree

Agree

Neutral

Disagree

Strongly
Disagree

1	The tasks were too difficult	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	The tasks represented my own driving style well	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	My main goal was to drive safely.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	I wanted to accomplish the tasks quickly.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	I wanted to reach a high score	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	It felt more like a game than a real situation.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Additional comments for the lane change task:

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¹C. Bauer, "Interview on Gamification [Part 2]: Gamification in 2020", <http://goo.gl/0u0Br2>

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List of Acronyms

GUI	graphical user interface
ACC	Adaptive Cruise Control
HMI	human machine interface
IEEE	Institute of Electrical and Electronics Engineers
TUM	Technische Universität München
VMI	Fachgebiet Verteilte Multimodale Informationsverarbeitung
OIT	Organismic Integration Theory
HCI	Human-Computer Interaction
XP	Experience Points
RPG	Role-Playing Game
CAN	Controller Area Network
IVIS	In-Vehicle Infotainment Systems
OBD	On-Board Diagnostics

Bibliography

- [1] S. Diewald, A. Möller, L. Roalter, and M. Kranz, "DriveAssist - A V2X-Based Driver Assistance System for Android," in *Mensch & Computer Workshopband* (H. Reiterer and O. Deussen, eds.), pp. 373–380, Oldenbourg Verlag, 2012.
- [2] S. Diewald, T. Leinmüller, B. Atanassow, L.-P. Breyer, and M. Kranz, "Mobile Device Integration and Interaction with V2X Communication," in *19th World Congress on Intelligent Transport Systems (ITS)*, Oct. 2012.
- [3] D. Kern and A. Schmidt, "Design space for driver-based automotive user interfaces," *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications - AutomotiveUI '09*, p. 3, 2009.
- [4] H. Sacher, *Gesamtheitliche Analyse des Bedienverhaltens von Fahrzeugfunktionen in der täglichen Nutzung*. PhD thesis, Technische Universität München, Munich, 2009.
- [5] G. Geiser, *Mensch-Maschine Kommunikation*. München: Oldenbourg, 1990.
- [6] T. C. Lansdown, N. Brook-Carter, and T. Kersloot, "Distraction from multiple in-vehicle secondary tasks: vehicle performance and mental workload implications," *Ergonomics*, vol. 47, pp. 91–104, Jan. 2004.
- [7] D. G. Novick and K. Ward, "Why don't people read the manual?," in *Proceedings of the 24th annual ACM international conference on Design of communication*, SIGDOC '06, (New York, NY, USA), pp. 11–18, ACM, 2006.
- [8] K. Bessiere, I. Ceaparu, J. Lazar, J. Robinson, and B. Shneiderman, "Social and psychological influences on computer user frustration," *Media access: Social and psychological dimensions of new technology use*, pp. 91–103, 2004.
- [9] I. Ceaparu, J. Lazar, K. Bessiere, J. Robinson, and B. Shneiderman, "Determining causes and severity of end-user frustration," *International Journal of Human-Computer Interaction*, vol. 17, no. 3, pp. 333–356, 2004.
- [10] D. G. Novick and K. Ward, "What users say they want in documentation," in *Proceedings of the 24th annual ACM international conference on Design of communication*, SIGDOC '06, (New York, NY, USA), pp. 84–91, ACM, 2006.

- [11] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemporary Educational Psychology*, vol. 25, pp. 54–67, 2000.
- [12] E. L. Deci, R. M. Ryan, and K. A. Miller, "Intrinsic motivation and self-determination in human behavior," *Contemporary Sociology*, vol. 17, no. 2, p. 253, 1988.
- [13] R. deCharms, *Personal Causation*. Academic Press, 1968.
- [14] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: Defining "gamification"," in *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, MindTrek '11, (New York, NY, USA), pp. 9–15, ACM, 2011.
- [15] R. Caillois, B. M. Berger, and M. Barash, "Man, play, and games.," *American Sociological Review*, vol. 28, no. 4, p. 651, 1963.
- [16] B. Reeves and J. Read, *Total Engagement: Using Games and Virtual Worlds to Change the Way People Work and Businesses Compete*. Harvard Business School Press, 1 ed., Nov. 2009.
- [17] J. Juul, *Half-Real : Video Games between Real Rules and Fictional Worlds*. The MIT Press, Nov. 2005.
- [18] M. Prensky, "Digital natives, digital immigrants part 1," *On the Horizon*, vol. 9, no. 5, pp. 1–6, 2001.
- [19] A. Möller, A. Thielsch, B. Dallmeier, L. Roalter, S. Diewald, A. Hendrich, B. E. Meyer, and M. Kranz, "MobiDics – Improving University Education With A Mobile Didactics Toolbox," in *Ninth International Conference on Pervasive Computing (Pervasive 2011), Video Proceedings*, (San Francisco, CA, USA), June 2011.
- [20] H. Lee and Y. Y. Doh, "A study on the relationship between educational achievement and emotional engagement in a gameful interface for video lecture systems," in *Proceedings - 2012 International Symposium on Ubiquitous Virtual Reality, ISUVR 2012*, pp. 34–37, 2012.
- [21] S. Nicholson, "A user-centered theoretical framework for meaningful gamification," in *Proceedings of Games+Learning+Society 8.0*, pp. 1–7, 2012.
- [22] B. K. Jiang, "The dangers of gamification," *America*, p. 7, 2011.
- [23] S. Priebatsch, "The game layer on top of the world," *TED Talks*, 2010.
- [24] F. L. Law, Z. M. Kasirun, and C. K. Gan, "Gamification towards sustainable mobile application," *2011 Malaysian Conference in Software Engineering*, pp. 349–353, Dec. 2011.
- [25] M. Gualtieri, "Mobile app design best practices," *Reproduction*, pp. 1–26, 2011.

- [26] S. Diewald, A. Möller, L. Roalter, T. Stockinger, and M. Kranz, "Gameful Design in the Automotive Domain: Review, Outlook and Challenges," in *Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '13, (New York, NY, USA), pp. 262–265, ACM, 2013.
- [27] C. Dorrer, *Effizienzbestimmung von Fahrweisen und Fahrerassistenz zur Reduzierung des Kraftstoffverbrauchs unter Nutzung telematischer Informationen*. PhD thesis, Universität Stuttgart, 2003.
- [28] R. Ecker, B. Slawik, and V. Broy, "Location Based Challenges on Mobile Devices for a Fuel Efficient Driving Behavior," in *Proceedings of 5th International Conference on Persuasive Technology*, (Copenhagen, Denmark), pp. 5–8, 2010.
- [29] S. Deterding, "Pawnd. Gamification and Its Discontents," *Playful 2010*, 2010.
- [30] S. Diewald, A. Möller, L. Roalter, and M. Kranz, "Gamification-supported Exploration of Natural User Interfaces," in *Adjunct Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2012)*, pp. 47–48, Oct. 2012.
- [31] S. Diewald, A. Möller, L. Roalter, and M. Kranz, "Mobile Device Integration and Interaction in the Automotive Domain," in *AutoNUI: Automotive Natural User Interfaces Workshop at the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '11, Nov.–Dec. 2011.
- [32] R. V. Eck, "Digital game-based learning: It's not just the digital natives who are restless," *EDUCAUSE Review*, vol. 41, no. 2, pp. 1–8, 2006.
- [33] M. Höchsmann, "Ausarbeitung „CAN-Bus“,," tech. rep., Fachbereich DCSM der Hochschule Rhein-Main, 2010.
- [34] R. Neuss, *Dokumentation E64 Mockup*. Usaneers GmbH, Munich, Germany, 1.2 ed.
- [35] S. Mattes, "The lane-change-task as a tool for driver distraction evaluation," in *Quality of Work and Products in Enterprises of the Future* (H. Strasser, ed.), pp. 57–60, Stuttgart: Ergonomia, 2003.
- [36] S. G. Hart and L. E. Stavenland, "Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research," in *Human Mental Workload* (P. A. Hancock and N. Meshkati, eds.), ch. 7, pp. 139–183, Elsevier, 1988.
- [37] J. Krumm, *Ubiquitous Computing Fundamentals*, ch. 4. Chapman & Hall/CRC, 1st ed., 2009.

-
- [38] H. Pashler and J. C. Johnston, "Attentional limitations in dual-task performance," in *Attention* (H. Pashler, ed.), pp. 155–185, UK: Psychology Press, 1998.
- [39] S. Mattes and A. Hallén, "Surrogate distraction measurement techniques: the lane change task," in *Driver distraction* (M. A. Regan, J. D. Lee, and K. L. Young, eds.), pp. 107–122, New York: CRC, 2009.
- [40] M. Schwalm, A. Keinath, and H. Zimmer, "Pupillometry as a method for measuring mental workload within a simulated driving task," in *Human Factors for assistance and automation* (D. de Waard, F. Flemisch, B. Lorenz, H. Oberheid, and K. Brookhuis, eds.), pp. 75–88, Maastricht, the Netherlands: Shaker Publishing, 2008.