Gamified Training for Vehicular User Interfaces – Effects on Drivers' Behavior

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***Abstract*—In densely populated areas, we currently see a paradigm shift in personal mobility. For the younger generation, car usership is gradually replacing the need of car ownership. However, for example, when relying on car sharing solutions, users often spontaneously drive cars they are not used to. Results are increased stress and a higher risk of accidents. For that reason, we present a mobile application-based training solution for vehicular user interfaces. The evaluation of the training application has shown that a short training cannot counteract the negative influence of operating comfort car functions while driving. The use of game design elements in the application increased the training motivation, but also lowered the information reception.**

I. Introduction and Motivation

The ongoing urbanization is changing the shape of mobility in tomorrow's cities. Especially in large and congested cities, the need of owning a car is gradually decreasing with the rise of new intermodal door-to-door mobility solutions. In a recent survey by KPMG[1], only 46 % of younger consumers ($<$ 25 years) rated that owning a car is extremely or very important for them, opposed to 76 % for 25 to 35 years and 78 % for 35 to 50 years old consumers. For the younger generation, mobility has to fulfil the three key aspects spontaneity, flexibility, and sustainability [1]. In order to fulfil the demands, modern mobility-as-a-service (MaaS) solutions have to combine public transportation with means of individual transportation [2]. One solution for filling the individual mobility gap is car sharing. Provided in a free float manner, offering one-way support and pay-as-you-go billing, car sharing allows for instantaneous car usership when needed.

However, when driving an unknown car – as it is often the case with car sharing – the interaction with its user interfaces and the operation of (comfort) vehicle functions can be very challenging and thus cause safety concerns. A study of the U.S. National Highway Traffic Safety Administration (NHTSA) has revealed that secondary and tertiary tasks in vehicles, such as adjusting the radio and other devices integral to the vehicle, contribute to over 22 % of all investigated crashes and near-crashes. However, it has been shown that many of these problems can be overcome by a short training phase [3].

In this paper, we describe a novel concept for automotive user interface training that uses gamification for boosting the users' motivation. The concept has been implemented in a mobile application (see Fig. 1) and its influence on the driving behavior has been evaluated in a driving simulator study. Our work represents an example for targeting at the potential users' preferences: a mobile application that can be used on the move, feels like a game, and provides a basis for a relaxed journey.

[1] http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/global-automotive-executive-survey/Documents/2014-report.pdf, last accessed Apr. 16, 2014

Fig. 1. The first prototype of our gamified vehicular user interface training application for mobile devices offers a quiz mode in which users have to solve tasks in a realistic virtual cockpit. This stimulates the trial-and-error behavior, which shall rise the motivation of self-determined exploration.

The structure of this paper is as follows. We begin with presenting related work, where we focus on vehicle functionality and driver behavior, existing training solutions and on particularities of gamification. Subsequently, we describe the implemented gamified training application. We introduce the conducted study and present our experimental findings in a comprehensive way. We finally share lessons learned in order to inform the design of future automotive user interface training solutions.

II. Background and Related Work

A. Assessment of Vehicle Functionality and Driver Behavior

An analysis of the in-car design space by Kern and Schmidt shows the enormous increase of mainly comfort functions and, with that, control elements in the last few years. The analysis highlights that the development is not only driven by the car manufacturers, but also the drivers demand for more comfort. With longer commutes, a car becomes more than just a means of transportation. It can be seen as "multi-functional living space" where people consume media, communicate, or even work [4]. With the increasing number of control elements, a one-to-one mapping is no longer possible and the introduction of multi-purpose input/output-devices was necessary. The different functions are no longer obvious and a certain amount of experience and training is necessary. For our concept, we assume that especially secondary (mostly safety increasing functions, e.g., activating turning signals or windshield wipers) and tertiary driving tasks (comfort functions including infotainment system) need to be trained. The primary task of driving should be well-practiced and equal between different car types and makes (the difference of automatic and manual shifting is not considered here).

Even though tertiary tasks are not essential for operating a vehicle, they are performed regularly during the drive and thus heavily influence the driver and the driving performance. In a mental workload experiment, Landsdown et al. examined possible safety impairments of drivers when facing multiple simultaneous tasks [5]. The results show that operating secondary and tertiary tasks leads to increased workload, which results in decreased headway and higher brake pressure. Drivers often compensate for the higher mental load by reducing their speed. Higher mental workload is especially the case when drivers operate functions in a cockpit they are not used to [6]. In those cases, visual distraction is the major reason for the higher workload [5].

Wu et al. have analyzed the vehicle entry and start process including the necessary adjustments that are essential for a safe drive [7]. Surveys have shown that many people do not make the necessary adjustments (e.g., seat, rear-view mirrors, steering wheel) before they start the drive. In many cases, this is made up during the first few meters of the drive and sometimes the adjustments are completely skipped. However, wrong adjustments are often the cause for accidents [8]. There are multiple reasons why people make inconvenient adjustments or even skip the adjustment step [9]. Besides being in a hurry, some drivers also have problems with the operation of the different levers for manual or powered adjustments of the seat, rear-view mirrors, or steering wheel position. Besides adjusting safety- and driving-relevant elements, a more relaxed journey is also possible when other secondary and tertiary comfort functions are controlled before the drive starts, e.g., entering the destination in the navigation system, setting the temperature for the automatic climate control, or choosing the desired radio station. For that reason, our training concept provides the driver with clues for a complete trip with an unknown car – from car entry to parking the car. All relevant user interface elements are explained and the user is guided through the complete process.

B. Presenting Educational Information

In in-depth interviews, Novick and Ward explored why people avoid using manuals when facing usability issues with digital systems [10]. The interviews revealed that highest frustration arises in situations when users have issues with elements that are not regularly used (independent of the self-assessed proficiency of the users). That means, the target group of our training solution are not only drivers with no experience with a certain car, but also more experienced users that need to be trained on less known comfort functions. In addition, the results showed that many people do not consult printed manuals as they are hard to handle and difficult to navigate.

Digital help suffers from the same drawbacks when the information is presented statically and not processed for easier browsing [11]. Missing terminology is another problem that makes it difficult to find an appropriate solution. For usable digital help systems, users demand visual explanations (pictures and videos), step-by-step solutions and examples. In our mobile training application, we focus on simplicity; pictures and animations are used for demonstrating the use of controls and everyday language is used for naming and explaining functions and elements.

C. Gameful Design for Training Motivation

Knowing that informative documentation is often not attractive to users, an approach for raising the level of attractiveness of such an educational application is needed. In order to move people to do something, research mainly distinguishes between intrinsic and extrinsic motivation [12]. Intrinsic motivation is often described as a strong force that arises from a task itself. In contrast, extrinsic motivation is based on external forces such as separable striving outcomes (e.g., material rewards) or control from the outside (e.g., pressure). In order to set on intrinsic motivation, we ought to assume that drivers willingly choose to familiarize with the vehicle's functions, e.g., to reach a high level of competence and more autonomy that would lead to a more relaxed drive. However, knowing that many drivers do not concern themselves with the user interface of unknown vehicles due to lack of interest and time, intrinsic motivation will not be sufficient in that case.

A high level of motivation can also be reached through different kinds of extrinsic factors [12], such as external gratifications, fulfilling the need of belongingness (social factors), or contributing to a larger goal. Many of these factors can be found in games. This has been exploited in so-called *serious games* in many different areas such as the military, academics, medicine, or professional training [13]. The entertaining gaming effect is used to educate, train, and inform their "player" [14]. In recent years, it has been shown that gameful design can likewise be a benefit for applications that are not framed in game scenarios. The location-based application *Foursquare* and the science puzzle application *FoldIt* [15] are prominent examples of gamified applications that award users with points and badges for completing certain actions. Deterding et al. researched the current use of gamification and proposed the following definition: "Gamification is the use of game design elements in non-game contexts" [16].

In order to create high motivation with game design elements, according to McGonigal, four things need to be considered: satisfying work (consisting of a clear goal and next actionable tasks), the hope/experience of being successful (feedback system), social connection, and meaning (e.g., contribute to a superior goal) [17, p. 53]. According to Zichermann and Cunningham, the basic game mechanics are points, levels, leaderboards, badges, onboarding, challenges/quests, and engagement loops [18].

Since gameful design can arouse sustainable motivation and strong commitment, it has found its way into the automotive domain [19], [20]. However, so far it is mainly used for marketing, eco-driving, and driving safety. In the following section, we propose our approach of a gamified vehicular user interface training.

III. Gamified Training Concept

Our training concept aims at novice and advanced beginner drivers of vehicle models. The main scenario covered in this work are users of the younger generation that regularly change car models, for example, because they are using car sharing vehicles in their daily mobility. In order to support the mobility of the targeted group, the concept is based on a mobile application that can be used on the move.

A. Exploration Mode and Quiz Mode in the Virtual Cockpit

Especially users that are avoiding manuals prefer the *trial-and-error* method for gaining proficiency [10], [21]. However, this method causes unnecessary distraction and thus safety risks when performed in moving vehicles. In our concept, this method is addressed by a one-to-one mapped virtual representation of the vehicle's interior. That way, users can explore the cockpit and the functions of the different controls before they enter the vehicle. The exact content and training depends on the respective vehicle models. In our scenario, a user plans a multimodal trip with the help of a mobile application. In this application, the car sharing vehicle could, for example, be directly reserved and while the user is on the way to the car, the application could automatically load the respective training for the reserved vehicle.

The *exploration mode* offers a cockpit and a function view. In the cockpit view, a virtual representation of the real cockpit is shown. The users can freely roam and find the input elements themselves. When clicking on an element, a visual explanation shows how to operate the input element and what functions are connected to it. The visual explanation is either a still image or an animation. When an input element can be operated in multiple ways, the ways are explained one after the other. The functions view consists of a list indicating what functions have been found so far. Missing objects are greyed out and, when clicked, users get a hint where to find this function in the cockpit view. When clicking on an already discovered element, the visual explanation is shown and the element can be highlighted in the cockpit view. The function view serves as a reference list where users can look up functions.

The *quiz mode* supports establishing the explored functions and the layout of the vehicle cockpit. The quiz mode makes use of both the cockpit and the function view. The tasks in the quiz consist of finding the element for operating a given function in the cockpit view or choosing a function from a single choice list for a control element that is highlighted in the virtual cockpit. The time for answering a question is limited. Points are awarded for right answers and bonus points can be earned by answering quickly. A quiz consists of five questions and the achieved points are accumulated. The highest score is saved in order to compare the respective achievement.

B. Online Mode in Real Vehicle

Besides the exploration of and training with a virtual cockpit, the application can also be coupled to the bus system of a real vehicle [22]. This allows further training modes:

- *Online exploration mode* and *online quiz mode*: The operation of certain control elements can be detected on the vehicle's bus system. That enables to perform a short training in the real cockpit before a drive starts. Similar to selecting elements on the virtual cockpit, the driver can work with the real cockpit. This mode is only available when the vehicle is parked.
- *Background assessment mode*: The application monitors the operation behavior of the users and at the same time records accelerations and speed while the user is driving. After the drive, the application analyzes the recorded driving and operation behavior and can give hints what should be trained in more detail or what operations should be avoided next time. During the drive, the application only indicates that the drive is monitored, no further information is displayed to avoid additional distraction.
- *Preset mode*: The preset mode allows restoring saved presets (e.g., adjustments of powered rear-view mirrors, and seats, or settings of the audio system, automatic climate control etc.). This can either be done by sending stored information on the vehicle's bus system when allowed, or by reading the sensor values on the bus and giving feedback when the saved values are reached. This mode is also only available when the vehicle is parked.

C. Employed Game Elements

The *goals* of the application are to inform the user of the vehicle functions and raise awareness of their operating behavior inside the vehicle. Both goals are stated in the application's description and are identifiable in the tasks (explanation of the functions and hints via background mode). The *rules* are also in the respective mode descriptions. The tasks are intentionally kept very simple (e.g., clicking on identified control elements in the virtual cockpit) what allows for an easy identification of the next actionable steps. Feedback is given via a progress gage that shows how many elements have been found and how many are still missing. In the quiz mode, the user also receives feedback on the progress and a score is awarded for correct answers. The score is kept in a highscore list to allow for ego-involvement [23] which shall motivate to repeat levels to improve the score. In a later version, it is also planned to be able to compare the score with other users. Before the user can access the quiz mode, milestones have to be reached, which can be seen as intermediate goals that guide the user.

However, the scoring mechanism is not central to the application; users can also advance with low scores. This is to avoid outshining the underlying non-game training context, which is of higher importance than the game mechanics. We avoid an extensive use of a badge system as badges are often seen as very generic and organization-centered [24]. For example, a badge for taking a quiz ten times will shift the focus away from intentional repetition to a mechanic, dull task.

IV. Prototype

In order to evaluate the previously presented concept, we built a prototype for the Android platform [25]. We implemented the exploration mode and quiz mode. The exploration mode includes the virtual cockpit and function view. The quiz is not yet started automatically during the exploration, but can be started from the application's main menu, which is

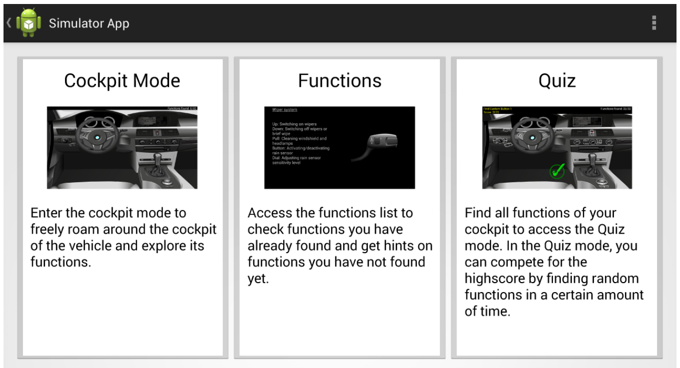

Fig. 2. The main menu of the mobile application. It allows access to the exploration mode ('Cockpit Mode' and 'Functions') and to the quiz mode.

Fig. 3. The cockpit mode of the mobile application. By clicking on an interactive element in the cockpit, the application shows usage details (see Fig. 4) and awards points to the user for newly found functions.

depicted in Fig. 2. For the driving simulator evaluation, we had access to a real chassis-based BMW series 5 (model 2005) driving simulator. The training modes were created to match the interior and functions of the experiment environment. The cockpit view is a realistic recreation so that the driver can make a connection between the view in the application and the real cockpit (see Fig. 3); only the steering wheel was shrunk so that is does not cover other control elements. The user can interact with the cockpit through the standard Android interaction gestures. A total of 32 elements were implemented. In the exploration mode, the progress indicating the found elements is shown in the top right corner. When an element has been found, a white outline is added to mark the already explored ones. Each control element has an own description page with textual and visual explanation of the element and the connected functions (see Fig. 4). The function view lists all available functions. Functions that have not yet been explored in the cockpit mode are grayed out. When clicking on a grayed out function, a message with a hint where to find the element in the cockpit pops up. When clicking on already explored functions, the explanation is started.

The quiz mode is realized as an overlay of the cockpit view (see Fig. 1). The current quiz task and the score are displayed in the top left corner. Visual and auditory feedback for indicating right and wrong answers is given when a user clicks on an element. When the quiz is over, the user is presented a scoreboard presenting the final score (points for

Fig. 4. The details view explains the usage of the different interactive elements. There is also a walk-through for the vehicle's infotainment menu. The example in this figure shows details on the wiper stalk switch.

correct answers + time bonus − points for wrong answers). In addition, the highscore is shown and the user is informed when a new highscore was reached.

The online mode was realized as a GUI application running on a PC connected to the in-car displays. It can read all bus messages and display content on the dashboard and the display in the center stack. The current implementation represents only the background mode of the presented concept. The application calculates a score by evaluating if and how fast predefined operation tasks are performed during the experiment. The score is automatically displayed after the last defined operation task.

V. Experimental Evaluation

We evaluated the described training concept regarding its effects on the driving performance and functions operation. The experiment provides answers to the following research questions:

- Research question 1 (RQ1): Is the influence of secondary and tertiary tasks on the driving performance a significant problem?
- RQ2: Is the training effect of the mobile app similar to the effect of gaining experience in the real car?
- RQ3: Does the use of the training application influence the detection rate and operation of vehicle functions?
- RQ4: Will subjects perform safety-critical actions or even follow dangerous recommendations while driving in order to get a higher score from the training system?
- RQ5: How does gamification affect the training?

A. Experiment Setup and Design

In order to measure the effect of the gamified training application, the participants were randomly divided into two groups (between subjects design):

1) Without any training (control group).
2) 10 minutes training with the mobile application (experiment group).

The metrics included required distance for task completion, lane deviation, subjective perceived workload, and ratings on

Fig. 5. The driving simulator used for the evaluation of the in-vehicle mode (online mode) of the training concept. It is the real cockpit of a BMW 5-series. The training application controls parts of the dashboard and the display on top of the center stack, and can log most controls by monitoring the vehicle's bus system.

a questionnaire. The perceived workload was measured by the NASA Task Load Index (NASA-TLX) questionnaire. The additional questionnaire asked about previous knowledge of the subjects and let them rate statements concerning their motivation as well as their perception of the gamefulness of the overall experiment.

The experiment was performed in a real car cockpit-based driving simulator (BMW series 5, model 2005). The simulator is depicted in Fig. 5. The driving task was the so-called *Lane Change Task* by Daimler [26]. The maximum speed was set to 60 km/h. The secondary and tertiary operating tasks to be performed by the subjects were shown on the lower part of the dashboard and were triggered automatically based on the driven distance. The subjects were instructed to focus on their speed, to perform the lane changes indicated by the simulation tool, and to keep their track. Although the participants should focus on driving safety, the displayed operating tasks should be performed as fast as possible. The operating tasks are summarized in Table I.

The experiment began with a brief introduction for both groups. In a pre-experiment questionnaire, demographic data, driving experience and experience with technical systems such as smartphones were gathered. Afterwards, the experiment group got a short introduction to the mobile application prototype, which ran on a Google Nexus 7 tablet PC. Then, the subjects could freely explore and use the gamified application for a maximum of 10 minutes. The subjects in the control group immediately progressed with the driving task.

The driving task consisted of four laps (each around 3300 m, ~3.5 minutes) in the Lane Change Task (LCT) simulation. In the first lap, subjects got an introduction to the simulation environment and to the LCT. In the second lap, baseline data on the driving performance was recorded. In the baseline lap, no extra operating tasks had to be performed. For the last two laps, subjects had to perform the additional operating tasks (cf. Table I) in parallel to the normal driving task. After the third lap, a summary of their operating performance in form of an automatically calculated score (composed of accomplished task score and time bonus) was presented to the subjects. Before they started the fourth lap, the experimenter told the subjects that the score is rather low and they could get into a highscore list when they perform the operation tasks faster and more accurate in the next lap. After each lap, subjects had to do a subjective assessment of their mental workload with the NASA-TLX questionnaire.

B. Participants

For the first test, we recruited 30 subjects between 19 and 28 years (median = 25 years, standard deviation $\sigma = 2.53$). There were 5 female and 25 male participants. Most of the participants were students or research assistants. The average experiment duration was 35 minutes. Subjects received a direct compensation for their participation in form of a €5 gift card for an online retailer. The average driving experience was 6.0 years ($\sigma = 2.53$). The subjects were randomly assigned to the experiment (participants P16 to P30) and control group (P1 to P15). A Student's t-test ($\alpha = 0.05$, two-tail) on the driving experiences of the control and the experiment group showed no significant difference ($P(T \leq t) = 0.069$). In addition, there were no significant differences in experience with and interest in technical devices between both groups. One subject (participant P2, control group) works as a part-time chauffeur for a BMW fleet service and, thus, is very acquainted with the cockpit of the simulator. Two subjects (P8 and P20) dropped out after lap 3 but completed the post-experiment questionnaire.

C. Results of the Driving Experiment

The presentation of the results focuses on the parts relevant for providing answers to our research questions. The calculation of the mean lane deviation in meters was done with the *LCTAnalysis* tool. Instead of working with absolute numbers, we refer the results to baseline measurements that were performed in the second lap.

In comparison to the second lap (baseline, mean $\mu = 0.81\,\text{m}$, $\sigma = 0.23$ for control group, $\mu = 0.85\,\text{m}$, $\sigma = 0.22$ for experiment group) without additional operating tasks, the lane deviation increased for the control group on average about 48.7 % ($\sigma = 0.43$) for the third lap and 39.6 % ($\sigma = 0.46$) for the fourth lap. The experiment group had slightly better results. Their lane deviation increased by 42.1 % ($\sigma = 0.27$) for the third lap and 23.7 % ($\sigma = 0.27$) for the fourth lap. However, no significant differences could be found between the results of both groups (lap 3: $P(T \leq t) = 0.65$, lap 4: $P(T \leq t) = 0.26$). In order to answer RQ1 (effects of secondary and tertiary tasks on driving performance), significance of the lane deviation increases for all subjects was again checked with a two sample t-test ($\alpha = 0.05$, two-tail). The significance can be confirmed for lap 3 ($P(T \leq t) = 7.83 \times 10^{-7}$) as well as for lap 4 ($P(T \leq t) = 3.1 \times 10^{-3}$), both compared to baseline.

The task completion rates were almost equal for both groups (see Table I). The only significant difference can be seen for task T4. The completion rate for the active cruise control task is twice as high for the experiment group as for the control group. In Table II, the task completion distances are

TABLE I. Task completion rates for operating tasks. There were 15 participants in both groups for the third lap. For the fourth lap, in each group one subject decided to end the driving experiment early.

Task	**Lap 3**		**Lap 4**	
	Control n = 15	Exp. n = 15	Control n = 14	Exp. n = 14
Task 1 (T1): Increase volume via steering wheel controls	93.3 %	93.3 %	100 %	100 %
T2: Change radio station via steering wheel controls	80.0 %	73.3 %	78.6 %	78.6 %
T3: Play CD: Sheryl Crow	80.0 %	73.3 %	100 %	92.9 %
T4: Activate Active Cruise Control	33.3 %	60.0 %	35.7 %	71.4 %
T5: Start Navigation to 'Home'	73.3 %	66.7 %	100 %	78.6 %

TABLE II. Task completion distance in meter. The tasks were triggered automatically at given distances. All participants drove 60 km/h. No significant differences could be found between both groups. The decrease of task completion distance from lap 3 to lap 4 is significant for tasks T2 to T5.

Lap	**Task**	**Control Group**		**Exp. Group**		$P(T \leq t)$
		Mean	σ	Mean	σ	$\alpha = 0.05$, two-tail
Lap 3	**T1**	56.7	31.2	61.4	26.5	0.67
	T2	90.2	36.6	103.1	40.0	0.43
	T3	303.9	161.6	334.7	34.4	0.60
	T4	165.5	136.0	186.6	110.2	0.77
	T5	344.13	115.6	412.9	112.1	0.18
Lap 4	**T1**	44.0	24.4	48.9	16.5	0.54
	T2	47.1	30.8	62.2	37.8	0.32
	T3	182.85	91.2	167.4	49.2	0.59
	T4	36.2	25.6	40.3	20.4	0.74
	T5	164.0	120.0	140.7	76.7	0.58

given for both laps. There is no significant difference between the groups, so that one can say that the training application did not influence the detection and operation of vehicle functions (RQ3). However, the decrease of the completion distance from lap 3 to lap 4 is significant for tasks T2 to T5.

In order to successfully complete all tasks, 109 control actions need to be performed per lap. During lap 3, the control group performed on average 141.2 ($\sigma = 22.5$) actions. With an average of 137.8 ($\sigma = 22.1$) actions, the experiment group's result is not significantly different. This means that using the training application has no provable effect on the trial-and-error behavior of the users. In lap 4, the numbers increased to an average of 159.1 ($\sigma = 26.8$) actions performed by the control group and 142.7 ($\sigma = 18.4$) actions for the experiment group. However, the increase of performed control actions from lap 3 to lap 4 is not significant ($P(T \leq t) = 0.065$). We then looked at the individual results of the participants. Two participants only solved a single task (T1, T4) each. They performed 90 (participant P8, control group) and 102 actions (P19, experiment group) respectively. P8 had the second highest absolute lane-deviation value and the highest mental workload value. She reported to have experienced a high level of stress and, thus, decided to drop out of the experiment after lap 3. P19 had the third lowest lane deviation in lap 3 and stated that his focus was on driving safely. In the fourth lap, he performed 169 actions and, opposed to the general trend of decreasing lane deviation, his lane deviation value rose by 18.5 %. P3 had the highest increase in control operations between the two laps. In lap 3, he only had 101 actions and could solve two tasks. With 223 actions in lap 4, he had the highest overall amount of operations per lap, but only could complete three tasks. With the rise of control operations, the lane deviation also increased by 35.6 % which led to the highest absolute lane deviation in the study. To check whether there is a linear relationship between the change in numbers of operations and the change in values of lane deviation for the two laps, the Pearson product-moment correlation coefficient was calculated. After removing the values of the two dropouts (P8, P20) and an extreme outlier (P2, a part-time chauffeur with very good knowledge of BMW vehicles), a moderate positive correlation was determined ($r(24) = 0.53, p = 0.004$).

TABLE III. Mean and standard deviation (σ) of rated statements concerning the driving experiment. The statements had to be rated on a 5-point Likert scale with 1 = 'strongly disagree' and 5 = 'strongly agree'. No significant differences between the groups can be observed.

Statement	**Control Group**		**Exp. Group**	
	Mean	σ	Mean	σ
The operating tasks were too difficult for me.	2.07	0.59	1.87	0.74
My goal was to drive safely.	3.27	1.03	3.67	0.98
My goal was to accomplish the tasks quickly.	4.34	0.62	4.27	0.70
My goal was to reach a high score.	4.07	1.03	4.20	0.77
The experiment felt more like a game for me.	3.47	0.92	3.34	1.05

The results from the subjective assessment of the mental workload with the NASA-TLX (weighted score from 0 to 100) correlate with the average lane deviation of the LCT. No significant difference was found between the groups. For the second lap (baseline without operating task), an average NASA-TLX score of 24.7 ($\sigma = 13.9$) was calculated. The third lap (first experiment lap with operating tasks) had an average score of 57.0 ($\sigma = 21.3$), the fourth lap resulted in an average score of 39.4 ($\sigma = 18.4$).

In addition, the subjects rated statements on the driving experiment on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The results are summarized in Table III. The goal was to measure whether the usage of the mobile application changes the perception of the driving task. However, no significant differences between the groups could be observed.

D. *Results of Training Application Evaluation*

At the end, the subjects in the experiment group ($n = 15$) rated statements on the mobile application on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The fun factor of the application was rated with an average score of 4.20 ($\sigma = 0.56$). The usefulness of the application was confirmed with an average rating of 4.27 ($\sigma = 0.46$). The subjects can further think of using such an application for unknown cars (mean $= 3.80$, $\sigma = 0.77$). Participants thought that the use of the application made the operating tasks easier during the driving experiment (mean $= 4.47$, $\sigma = 0.52$). Regarding the motivation, the subjects stated with an average score of 4.73 ($\sigma = 0.46$) that the quiz mode with the ability to make a high score motivated them to improve their initial score.

VI. Discussion and Lessons Learned

From the results in Tables I and II, we can see that the use of the training application had no significant influence on secondary and tertiary task completion and driving performance. However, the learning effect leads to a significant reduction of task completion distance for T2 to T5 when comparing the results from lap 4 to those of lap 3 (see

Table II). The gained experience in lap 3 leads to a lower lane deviation, higher task completion rate, and lower task completion distance in lap 4. For that reason, the training effect of the mobile application is not comparable to the influence of gaining experience of real driving (RQ2). For future experiments, the learning effect of repetitive experiment conditions needs to be considered. The LCT is known to have an evident learning effect and performing the driving tasks again also enforces the learning effect, as shown by Petzoldt et al. [27]. In a follow-up study [28], they also determined that there are learning effects when making the participants work on realistic secondary tasks in addition to the primary driving tasks. Moreover, there were indications for a learning transfer between different tasks, if they are similar to some degree. We will investigate whether some operating tasks from our study are not sufficiently distinct to counteract this effect, especially both tasks operated on the steering wheel (T1, T2). For further studies, we will have to consider the previous experience of participants with both the LCT and the operating tasks to be completed.

The only task that produced a higher completion rate in the experiment group as opposed to the control group was the active cruise control task (T4). We believe this to be grounded in several factors. One factor is the general distribution and availability of cruise controls in cars the study participants had previous experience with. In the 2014 DAT report [29], a representative survey among 2,688 car buyers yielded that cruise control equipment was built into 47 % of existing cars, 44 % of new cars, and 31 % of pre-owned cars in Germany in 2013. In contrast to that, radio equipment was built into 97 % of existing cars, 98 % of new cars and 95 % of pre-owned cars. Another factor is the difference in positions and shapes in which cruise control interfaces are built by manufacturers. There are solutions using stand-alone levers (e.g., below the turn signal lever), combinations with the turn signal or windscreen wiper levers and on-the-wheel button solutions. Placement of controls for the other tasks (T1-T3, T5) is less scattered: radios, CD players, and integrated navigation systems are commonly found in the central stack. Steering wheel radio controls can only be arranged on the surface of the wheel. All this suggests that there is more to be learned about unknown cruise control interfaces than unknown radio interfaces for drivers in an unfamiliar car model.

While we did not see a difference between the numbers of performed actions for the two groups, we could prove a moderate linear correlation between the lane deviation and the number of performed actions. In addition to the observation that secondary tasks in general cause higher lane deviation, this shows that also the amount of performed actions is a decisive factor. That means that trial-and-error is not a desirable behavior for finding functions while driving and that the overall amount of necessary secondary operating tasks should be kept low. In order to reduce the number of necessary secondary operations, our concept offers the preset mode that shall guide the drivers through the process of adjusting comfort functions before starting a trip.

Subjects stated in the final interviews that the mobile application had both informative and game character. Especially the cockpit view and the function list have been seen as an information source. The quiz mode was rated to be more like a 'learning game'. However, when we observed the users interacting with the mobile application, we noticed that the informative character faded into the background (RQ5). Most subjects tapped systematically or completely randomly on the virtual cockpit in order to find all functions. Instead of reading the information, subjects tried to keep the game flowing. When a function was found, the description was often just quickly scanned and possible recommendations or usage hints were overlooked. When we mentioned this in the interview, the subjects stated that their goal was to activate the quiz mode quickly. A solution could be to implement a short compulsory break that allows the user to read the text. Another idea is to cut down the amount of information presented at a time. Alternatively, the textual explanation of functions could be enhanced with interactive graphics, video snippets, or audio.

For evaluating the game element 'score' and, thus, 'competition', a score was computed during the driving experiment and displayed to the subjects after completing a lap. We further intensified the 'competition' after the third lap by saying that they can enter a highscore list when they get more points in the fourth lap. From the values in Table III, it can be seen that on average the subjects concentrated more on the operating tasks and their score than on driving safely (RQ4). Although both groups had only slightly the feeling that the experiment is more like a game (see Table III), they disregarded the instruction that the main objective was to drive safely. When we asked the subjects why they had concentrated on the score, they mainly named the competition as decisive factor. The highscore list influenced even subjects who stated in the pre-experiment questionnaire not to be very competitive. That shows that competition is a very motivating factor for users to lose focus from the primary driving task. This coincides also with the observations of Deterding[2], which means that competition for safety critical applications should be avoided. As a lesson learned, we believe more thought will have to go into the balance between certain gamification elements and the matter of driving safely in future research. A main intention for our gamified mobile training solution is the reduction of stress and accident risks for driving with unfamiliar car models. With game elements that move safe driving out of focus for drivers, such a training tool could cause an effect in the opposite direction.

The main lesson learned from the evaluation and the tests during the development is that the concept should be developed iteratively and that after each slight change of the game mechanics a test is necessary. Even the change from one game element to another can be critical and needs to be evaluated thoroughly, as it might influence the focus of the users' attention.

VII. Conclusion and Future Work

We have presented a gamified vehicular user interface and functions training concept, and evaluated a working prototype in a driving simulator study. The experiments showed that secondary and tertiary tasks heavily impact the driving performance and that a short training with a recreated virtual cockpit cannot counteract the effect. However, gamification could motivate the users and made the training more enjoyable.

[2] http://en.slideshare.net/dings/pawned-gamification-and-its-dis-contents, slide 41, last accessed May 7, 2014.

On the other hand, we found indications that certain game elements – 'competition', in our case – have the potential to move the focus of the drivers away from safe driving and towards priorities like quick completion of tasks and reaching high scores. Thus, we will need a more careful consideration of which game elements might actually be suitable for the safety-critical domain of car driving. Furthermore, we will examine whether a general balance between the gamification aspects of the training solution and the background of enabling safer driving can be established.

We are currently enhancing the mobile application and conducting an experiment with the online mode of the concept. We will investigate whether the training effect with a recreated virtual car interface (mobile application) is comparable to the effect when training with a real car interface (online mode). The comparison will also be used to determine whether gamification in the real car distorts the perception of the seriousness of 'driving a real car'.

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