SESSION 4 :

ECODRIVING

Understanding the User Needs in the Electric Mobility System: a Survey Study

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ABSTRACT: Despite their potential for environmental impact reduction, Electric Vehicles (EVs) are still characterized by some peculiarities that make their acceptance by users a critical topic. Within the H2020 RESOLVE (Range of Electric SOlutions for L-category Vehicles) project, the specifications for the early concept design of a new L-category EV was based on a study of vehicle requirements. According to the European Regulation, a wide range of different vehicles are included in the “L–category”, each one being described in detail by the Reg.168/2013/EC “on the approval and market surveillance of two–or three–wheel vehicles and quadricycles. Starting from the lesson learned from literature, a survey was prepared in order to identify the needs and the attitudes of a range of potentail users, aiming at understanding their opinion and their propensity to use EVs. The Survey was proposed to open public using media such as social networks, website, project communication channels; relevant actors on the sector were contacted for the promotion of the initiative. The questionnaire included different sections related to person description, mobility needs definition, vehicle expectation and current knowledge on the EVs. As a first target, such approach was aimed to correlate the characteristics of the participants with the mobility needs they described. As a second target, their expectations in terms of performances and overall characteristcs were identified. Finally, the analysis of the perception of EVs confirmed that most users are correctly informed about EVs potential, but are still considering range as a limitation.

1 INTRODUCTION

European cities are increasingly congested due to the increased demand and usage of motor vehicles. These vehicles cater to the daily mobility needs of the residents, who mostly use them for commuting. As these vehicles become more numerous, emissions increase, parking gets scarcer, and noise levels affect the quality of life and health of city-dwellers. Moreover, the reduction of Greenhouse Gas (GHG) emissions and the expansion of renewable energies are crucial challenges for the future. Cars are responsible for around 12% of total EU GHG emissions. The 2015 and 2021 EC targets represent reductions of 18% and 40% respectively compared with the 2007 fleet average of 158.7g/km of CO2 [3].

2 EV: NEW VEHICLES FOR OLD DRIVERS

Such relevant emission reduction requires considerable restructuring in all sectors of the energy system. One of the main concern at this aim is the application of alternative propulsion systems. Pure electric powered transport holds the greatest potential for GHG emissions reductions, since the electricity can be produced from essentially carbon-neutral sources. Nevertheless, the EU is working to introduce electric vehicles beyond 2020, improving technology over time and developing the recharging infrastructure [2]. Even if the most feasible alternatives to traditional Internal Combustion Engine Vehicles (ICEVs) is represented by EVs, the rate of adoption of these vehicles is not high enough to have a significant impact on emissions and on urban living conditions [5]. This is because EVs are unable to compete with ICEVs especially due to low range achievable and high cost. According to a study on the topic [8], the limited instrumental attributes of EVs (e.g. low range) influence the overall judgement in terms of less joy and pleasure in owning and driving an EV and a negative social identity. It has been shown that these effects are largely dependent on how an Electric Mobility System (EMS) is set up as well as how it is used [4]. Adopting the perspective of human centered systems engineering three essential components should be taken into account when optimizing user-system interaction: technical system, user and task [4]. In this paper we will focus on the user, investigating the elements that make EV and EMS a feasible alternative to ICE and to traditional transport system. EVs driver copes with a range of new and unfamiliar technologies and it will be vital for automotive manufacturers to make the driver’s interaction experience positive and rewarding [9]. EV Drivers will encounter completely new concepts such as range management, charging procedures, recharging duration, very low noise, strong acceleration and limited space etc. [1], in addition to unfamiliar issues such as novel start and stopping procedures and the effect that driving style has on the potential mileage range [9]. The driver should understand how to utilize the EV's special driving qualities and should be supported in developing trust and understanding which factors affect the available range, in order to be able to reduce concerns and range anxiety [6] (i.e. tips on the proper use of the regenerative braking) [9]. Although EV field trials have a long-standing tradition, there is very little published research about how to design an EV dashboard in order to overcome these issues.

3 USERS' ACCEPTANCE OF EVS: A SURVEY ON POTENTIAL USERS

The history of EVs demonstrates that many obstacles – related to cost, to range and to charging infrastructure – have been limiting their diffusion. However, recent analysis on mobility needs demonstrated EVs potential. Since little data are available about Electric L-vehicles (powered two-three wheelers and quadricycles), a survey was lead within RESOLVE project. RESOLVE (Range of Electric SOlutions for L-category Vehicles) is an H2020 EU funded project (more details at http://www.resolve-project.eu/).

3.1 Scopes of the survey

According to a recent survey on potential EV users [8] vehicle purchase attitude is associated to three main categories of attributes: instrumental (functionality or utility provided – e.g. cost, performance), hedonic (emotional experience derived from use - joy, pleasure), symbolic (self or social identity related to the possession). The survey presented for the RESOLVE project was primarily aimed to assess the instrumental needs of the users in relation to EVs in general, and to L-category vehicles in particular. During the study, users' current knowledge and opinion were explored too. The survey was structured in 4 sections: 1. Person description; 2. Vehicle ownership and mobility needs; 3. Extended description of mobility needs; 4. Opinion on EVs.

Panel description

About 800 responses (20% in Italian and 80% in English) were collected. The identification of users' nationality showed that Italian users were predominant, but that also at least a 5% of share represented Great Britain, Austria, Germany, Poland and France. The age of the population was varied, being mostly represented by 25 to 64 years old users.

3.1.1 Transport habits and mobility needs

This part was aimed at understanding which transport modes are currently used by participants, based on the area where she/he lives. A crucial question to identify user needs was about the typical driving habitude. As demonstrated by former research [7], the needs can significantly vary between week and weekend days. Figure 1 shows that the most part of users (about 90%) declared that a distance below 60 km is usually driven for almost every weekday, while longer distances are driven on weekend days. Urban roads are the most frequently driven in weekdays; mixed patterns including rural roads and motorways are typical of weekend use. Both data, even if coming from self-estimation, are in line with researches based on trip diaries and GPS measurements [7]Errore. L'origine riferimento non è stata trovata.. The distance driven and ridden in a year shows that about 60% of total users are included within a value of 15000 km/year.

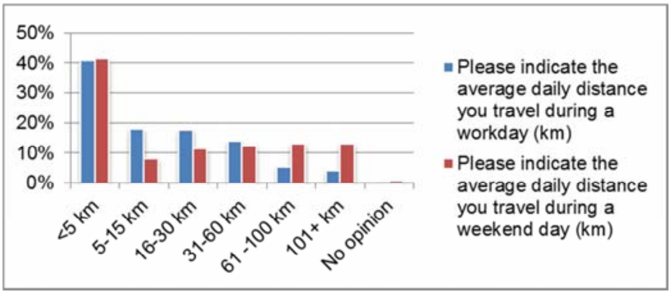

Figure 1 – Daily distance traveled by the users (self–estimation)

Most users are strongly sensitive on the transport-related issues; most of them (90%) are worried about “air pollution” and “noise pollution”. Traffic congestion, parking needs and mobility costs are mostly identified as critical issues. Regarding restricted traffic and pedestrian zones, the panel under study was divided: about 50% considered the accessibility to those zones as a potential issue.

3.1.2 Extended description of mobility needs

This section was aimed to collect the direct opinion of the users about their needs and their expectations on EVs. The user was asked to rank a number of options about the features desired for a hypothetical innovative vehicle.

Table 1 shows that such vehicle is perceived to be a mean of transportation for everyday use rather than for fun. Many positions in fact included the desire to transport a passenger and a certain amount of goods, to reduce the cost of fuel, to improve urban usability. Each raw represents a rank level; columns show the three most chosen answers. A direct question about range was provide too: about 65% of the users would be satisfied with a range below 120km, which is compatible with the performances of current EVs. Charging could be feasible in home position (55%), while lower percentages were evaluated for workplace (35%).

Table 1 - Results to the question "In case of using/buying a new vehicle for personal mobility, it is relevant to me..."

Rank	1st choice	2nd choice	3rd choice
1	Transport more than one passenger	Reduce the risk of being stuck in traffic	Reduce the cost of fuel
2	Transport a certain amount of goods	Park easily	Transport more than one passenger
3	Full protection from weather	Transport a certain amount of goods	Park easily
4	Possibility to drive it in cold winters	Access to motorways	Transport a certain amount of goods
5	Access to motorways	Transport a certain amount of goods	Full protection from weather

3.1.3 Opinion on electric vehicles

Looking at Figure 1, the positive qualities of EVs are known by the most part of users, which are also recognizing attributes like easiness to drive and comfort. About 19% disagree about environmental friendliness (a characteristic which, effectively, partially depends on the context of use) and the most part of users identify the range as a critical factor. Table 1 clearly shows that the main motivation for the use of EV is currently declared to be the costs, the efficiency and the environmental aspect.

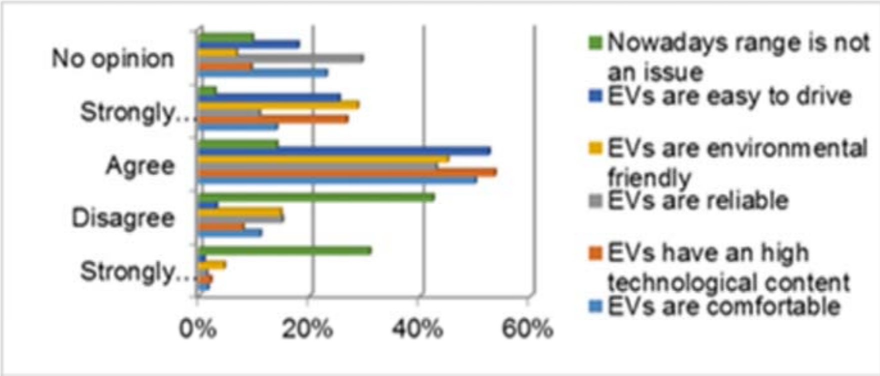

Figure 4 – Responses to "Do you agree/disagree that driving an EV gives you the following benefits in comparison with ICEVs?"

Table 2 – Extract from the results for the question "Please rank main reasons to use or buy an EV"

Rank level	1st choice	2nd choice	3rd choice
1	Fuel cost	Environmental impact reduction	Efficiency
2	Fuel cost	Cost of ownership	Efficiency
3	Cost of ownership	Efficiency	Fuel cost
4	Efficiency	Cost of ownership	Driving pleasure
5	Driving pleasure	Comfort	Access restricted traffic areas

4 CONCLUSIONS

As a conclusion, the study is significantly coherent with former literature experiences, demonstrating that for urban use most users agree on the usability of electric vehicles, but they also require an higher range. Considering that PTWs (Powered Two Wheelers) are perceived as "fun" vehicles, the panel highlighted a strong attention on aspect such as: i) cost; ii) Safety; iii) Transport capabilities (passenger, bag); iv) Urban usability and parking; v) Comfort; vi) Weather protection, in order to get a vehicle suitable for general purpose use. The panel under study due to the former experiences and the high average level of study is probably representative of a quite advanced and informed user, if compared with common driver.

5 ACKNOWLEDGEMENTS

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How to support eco-driving in electric vehicles? – An EV experimental field trail

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ABSTRACT: Eco-driving (ED) is a valuable technique to reduce CO_2 emissions. The gamification approach might constitute a useful opportunity to motivate and foster ED more extensive. The aim of the study was to investigate the impact of ED tip complexity combined with the concept of gamification for electric vehicles (EVs) on subjective assessments and driving data. Thirty drivers participated in an experimental field trial. Three systems were tested in a between-subject design: (1) AVERAGE consumption display (baseline), (2) an average consumption history display with ED tips (CHART) and (3) a system addressing a gamification approach with ED tips (GAME). In general, drivers evaluated all systems positive. There were no significant differences regarding workload, stress, acceptance, user experience and remaining range between the systems. However, the gamified system was rated more distracting and confusing. A trend of higher recovered kilometres can be seen for the gamified system. Although gamified ED systems involve a risk of distraction, their motivation potential seems more pervasive.

Keywords: Eco- driving, Gamification, In-vehicle information systems

1 INTRODUCTION

Eco-driving (ED) feedback systems can encourage and foster the motivation for an efficient driving style [1]. The relevance for ED has risen with the introduction of electric vehicles (EVs). Extensive charging times and the limited availability of charging infrastructure lead to a limited availability of driving range. ED has the potential to prolong range and in turn might counteract to range stress [2]. However, since driving itself is a complex task relying essentially on visual information processing [3] additional visual input from interfaces could increase workload and thereby pose a threat to traffic safety [4]. Currently the gamification approach is used for the design of in-vehicle ED systems by many OEMs, because of its persuasive and motivational aspect for green driving [5]. On the one hand gameful design might put additional workload on the driver or distract from the driving task and as a result impair traffic safety [6]. On the other hand mechanisms like reward and punishment positively influence the user experience (UX) and have the potential to permanently motivate an eco-efficient driving style in an easy and playful manner by increasing positive feelings like sympathy or pleasure and decrease negative feelings of fear or anger [5]. Additionally, ED feedback systems can expedite learning of ED. Well-known internal combustion engine vehicle (ICEV) ED-strategies are not always applicable to EVs. Adaption processes of ICEV ED-knowledge to EVs have to take place [7]. Instantaneous and especially gamified feedback systems could support the adaption period by providing real-time feedback [8].

Due to its potentially negative impact on traffic safety the investigation of complexity of ED systems combined with gamification is necessary [6, 9]. Previous studies about ED- feedback systems were mostly executed in simulated environments [1] and the influence of gamified feedback systems has not been investigated. Therefore, the primary aim of the current study was the examination of ED tip complexity combined with the gamification approach on subjective evaluations and its connection to remaining range in an experimental field trial. Summarizing the findings from previous research, the following hypotheses were investigated:

1. Due to higher complexity (additional visual input) ED systems (CHART, GAME) produce more workload, stress, distraction and confusion than simple average consumption (AVERAGE) feedbacks.
2. As a result of increased complexity, gamified ED systems (GAME) are rated more demanding, stressful, distracting and confusing than non-gamified systems (CHART).

2 User experience is rated more positively in gamified ED systems (GAME) than non-gamified ED systems (AVERAGE, CHART) because of its motivational (rewarding) mechanisms and results in higher recovered range in the gamified (GAME) condition.Method

1.1 Design

To investigate the influence of ED tip complexity and gamification on subjective evaluations of workload stress, distraction, acceptance, UX and remaining range, participants either received simple information about the average energy consumption (AVERAGE -Baseline), ED- tips with the average consumption in a bar chart (CHART) or ED tips following the principle of gamification (GAME).

1.2 Sample

In sum, *N* = 30 participants (*N* = 19 men, *N* = 11 women) with an average age of *M* = 37 years (*SD* = 10.50) completed the experimental field trial. Participants average weekly driving performance was 415.8 km (*SD* = 226, 98) and they had none or a little EV driving experience (*N* = 8, *M* = 49.25km, *SD* = 39.11km).

1.3 Procedure and data collection

Participants were recruited via the professorship's test subject database and randomly assigned to the experimental groups prior to the study. Firstly, subjects were informed about the purpose and procedure and the consent was obtained, followed by a preliminary questionnaire. Subsequently, subjects completed a practice drive with the EV and received standardized information about the specific ED systems. For the test drive, participants were instructed to drive as energy-efficiently as possible due to a low remaining range (approx. 70 km). In the following approximately 1,5 hours they drove a predefined route of 63 km in the area of Chemnitz, on city (15 km, max 60kph) and rural streets (20.8 km, max 100 kph) as well as highways (27.4 km, no speed limit). Following the test drive, the drivers rated: 1) the workload (NASA-TLX, [10]), 2) stress (How was your perception of stress caused by the ED tip in the center console?;1= No stress; 5= Very high stress), 3) distraction and confusion (I view this system that supports my driving as a source of confusion or distraction.; 1= Disagree Completely, 5= Agree completely, [11]) as well as the

4) acceptance ([Acceptance-Scale, [12]) and 5) user experience (AttrakDiff [13]). Advantages and disadvantages of the tested ED system were asked for in open format in the end. Additionally, the remaining range was recorded before and after the test drive (vehicle data) as well as the traffic density rated by the subjects and the experimenter and travel time. All subjective data was collected via the online-survey tool Limesurvey [14]. Further, eye-tracking data as an additional indicator for distraction was collected, but will not be analysed

and discussed here.

1.4 Material

The tested ED systems are available in the test vehicle BMW i3 (series vehicle). All drivers received information about the current driving style via the efficiency display. Figure 1 depicts all displays. The AVERAGE display demonstrated the lowest complexity and therefore can be considered as the baseline measurement. The *Consumption history* display (CHART) demonstrates the second level of complexity, because additional ED tips are presented in the center console. It depicts a bar chart (last 8 min.), top bars (>0) indicating the average energy consumed, and lower bars (<0) representing the average energy recovered. The *Driving Style Analysis Tool* (GAME) is considered the highest complexity, because ED tips (center console) are shown and gamification is implemented. It consists of a symbolized route and a table of values. The smoothness of the road symbolizes an efficient driving style. The gamification approach was operationalised by gaining stars in the categories “acceleration” and “anticipation”. The more efficient the driving style, the smoother the road and the more stars are presented (min = 0; max= 5). Table 1 summarizes the ED displays and its settings.

Table 1. Summary of ED displays and settings

	Efficiency Display and Eco Symbol	Center Console	Center ole - ED Tips	Gamification ach	Degree of plexity
AVERAGE	Yes	Average Consumption	No	No	1
CHART	Yes	Consumption History	Yes	No	2
GAME	Yes	Driving Style Analysis Tool	Yes	Yes	3

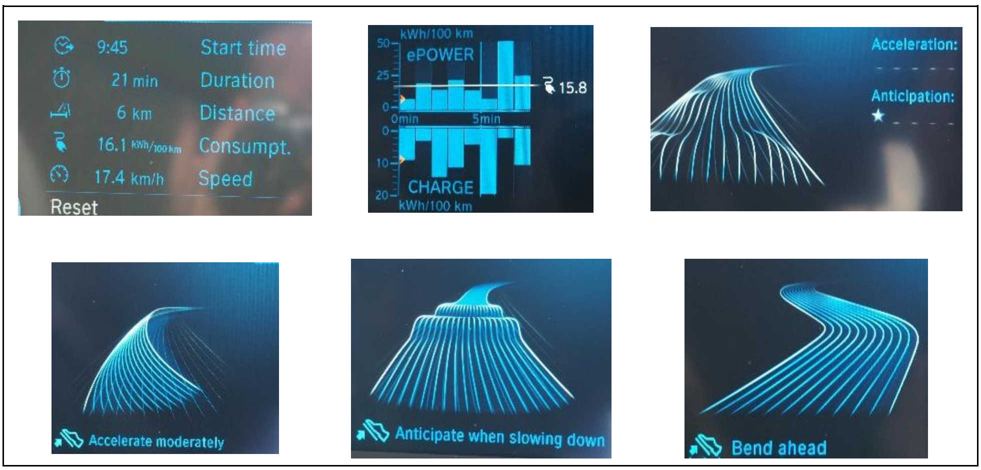

Figure 1. First Row: AVERAGE Display, CHART Display, GAME Display.

Second Row: ED tips (accelerate moderately, anticipate when slowing down and forthcoming traffic situation tips).

2 RESULTS

2.1 Questionnaire

To investigate differences between ED tip complexities in combination with gamification ANOVAS were executed. Descriptive and ANOVA results for the subjective assessments can be found in Table 2. Workload for all system was rather low and one-way ANOVA did not reveal a significant difference for complexity. Participants evaluated the systems as rather not stress inducing and ANOVA results did not became significant. Drivers rated GAME to be the most confusing and distracting, followed by AVERAGE. On average CHART was not rated confusing or distracting. In detail post-hoc test exposed a significant differences between the GAME and the CHART $F(1, 18) = 7.881$, $p = .012$, $f = 0.628$. Therefore, the first hypothesis has to be rejected while the second hypothesis can be confirmed for the single item confusion. Considering the UX, all systems reached positive values on the subscales but differences between the conditions were not found. The acceptance of the ED systems was rather useful and satisfactory, but did not differ significantly, which leads to a rejection of hypothesis 3 in terms of UX. Qualitative data considering advantages and disadvantages was coded and categorized [15]. Analysis showed that barely half of the participants (57%) criticize distraction caused by the feedback systems. Almost two-thirds (67%) point out the positive aspect of supporting and providing information about energy-efficient driving.

Table 2. Means and ANOVA results for subjective assessments by ED system.

	AVERAGE	CHART	GAME	ANOVA
Workload	30.16	28.56	30.38	$F(2, 27) = .184$, $p = .833$
User experience				
Pragmatic Quality	4.45	4.88	4.51	$F(2, 27) = .803$, $p = .458$
Hedonic Quality	4.05	4.37	4.34	$F(2, 27) = .991$, $p = .384$
Stimulation	4.50	4.68	4.44	$F(2, 27) = .237$, $p = .790$
Attractiveness	4.67	4.70	4.55	$F(2, 27) = .473$, $p = .628$
Stress	2.00	1.70	1.90	$F(2, 27) = .274$, $p = .762$
Acceptance				
Usefulness	1.22	1.02	0.60	$F(2, 16.318) = 2.080$, $p = .157$
Satisfaction	0.87	0.94	0.47	$F(2, 27) = 0.430$, $p = .655$
Confusion and Distraction	2.80	2.10	3.40	$F(2, 27) = 3.955$, $p = .031$

2.2 Driving data

To control for an influence of starting remaining range on subjective evaluations an ANOVA was conducted. Significant differences were not found, neither did the remaining range differ between groups after the test drive (Table 3). Hence, hypothesis 3 is rejected. Nevertheless, results indicate a trend in range prolongation (= starting - end remaining range - driven kilometres) with the highest range extension in GAME condition, followed by CHART and AVERAGE, *F* (2, 27) = 3.110, *p* = .061. As can be seen in figure

3. With respect to mean travel time significant differences were not observed. Nonetheless, a trend to longer travel times in the GAME condition can be observed (Table 3). Traffic density was rated medium, which did not significantly differ.

Table 3 Means and ANOVA results for driving parameters by ED system.

	AVERAGE	CHART	GAME	ANOVA
Range at Start (km)	78.70	72.10	75.80	$F(2, 27) = 0.790$, $p = .463$
Travel time (in min)	77.00	75.60	81.80	$F(2, 27) = 3.21$, $p = .056$
Traffic density (1-10)	6.00	4.40	5.44	$F(2, 26) = 1.55$, p = .232

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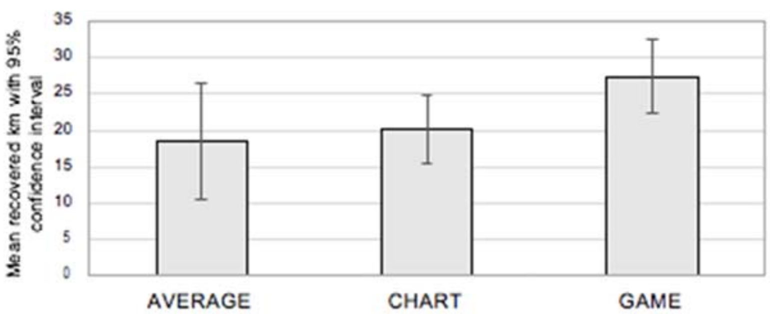

Figure 2. Mean recovered kilometers at the end of the trip.

3 DISCUSSION

This paper focuses on the impact of ED tip complexity combined with gamification on subjective assessments and driving parameters in an experimental field trial.

This study demonstrated that the indication of ED tips and especially gamified ED tips neither increase workload nor stress compared to more simple ED tip feedback systems (AVERAGE, CHART). Nevertheless, drivers' evaluation of distraction and confusion was negatively affected by gamification. Evaluations of workload, stress, distraction and confusion were solely assessed once, at the end of the trip. It is conceivable, that demands and stress as well as distraction or objective measures differ in dependence of the road context (city, rural, highway). When asked openly, subjects criticize potential distraction effects of ED tips, not only for the gamified system [6, 9]. However, all drivers endorse the advantages of ED feedback systems. Similarly to [1] results for UX and acceptance for ED tip systems were rated positive and supported the drivers in recovering energy and in turn kilometers. A negative impact of complexity and gamification on subjective assessments was not found. However, the expected positive effect of the gamified solution regarding attractiveness, stimulation, usefulness or satisfaction was not found. The lack of significance may be due to the studies between-subject design. Hence, the present data do not allow any conclusion about driver preferences for one of the ED tip systems. Although not significant, a trend of increased recovered kilometers due to feedback device can be seen, with the highest impact of the gamified version. A possible explanation might be that this finding may be the result of lower velocities in the gamified feedback solution. This interpretation is further supported by the notion of increased travel time within the gamified condition in conjunction with the stable traffic density evaluation and remaining range in the beginning for all systems. It can be assumed, that the use of gamification mechanisms like reward and punishment in ED tip systems, led to decreased travel speed. While smooth acceleration and rather low velocities lead to rewards, the opposite driving style leads to punishment and in consequence possibly to frustration, which should be avoided. The vehicles algorithm details for the calculation of recovered kilometers is not known, might be distorted and hence should be viewed with caution.

4 CONCLUSION

Eco driving is a valuable tool to reduce CO_2. Further, due to long charging times of and the missing charging infrastructure for EVs, ED has the potential to prolong range. The results of the study showed, that increasing ED tip complexity does not have a negative impact on the driver. Especially, combinations with gamification elements are a promising approach to motivate energy-efficient driving in real driving scenarios. The tested display solely implemented one gamified element and subjects criticized negative effects of distraction. Additional features like comparisons with a community heighten the complexibility further, which might improve eco-efficiently driving on the one hand. At the same time more disadvantage might emerge. Therefore, feedback and design consideration for gamified elements are essential to prevent the driver from negative effects like stress, confusion or distraction.

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SMART CHARGING SYSTEMS AS A SOLUTION TO OVERCOME GRID STABILITY PROBLEMS IN THE FUTURE?

A field study for examining the BEV user acceptance of a smart charging system

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ABSTRACT: Smart charging systems for battery electric vehicles (BEVs) are one promising smart grid technology that has the potential to facilitate the balancing of energy supply and demand. In the present contribution, users' evaluation of a smart charging system was investigated in real-life. Twenty BEV drivers compared conventional BEV charging with controlled charging while testing a smart charging system in a field study for 5 months. Before and after experiencing the prototype system, users' motivation, attitudes, willingness to use smart charging and charging behaviour were assessed via interviews and questionnaires. Results showed that users evaluate the system as rather acceptable, suitable for daily life, reliable and trustworthy. After using the smart charging system for approximately 2 months, users' judgments did not significantly differ from expectations before testing the prototype system; except for perceived suitability for daily life that was lower after testing the system. In sum, a smart charging system like the one implemented in this study is found to be assimilable in everyday life and results provided valuable indications for further development of smart charging systems.

1 INTRODUCTION

In times when the percentage of energy consumption that is covered by renewable energies increases worldwide, smart grid technologies are essential for balancing energy supply and demand. In ecomobility systems, smart charging systems for battery electric vehicles (BEVs) are one promising smart grid technology that interacts in real-time with smart grids in order to regulate charging processes depending on the grid load. Thus, they could help to overcome, for instance, grid overload problems (Amarossa & Cappuccino, 2012).

The potential of smart charging systems could increase if drivers keep their BEVs connected to the grid for longer periods of time or are flexible in terms of

the final state (%) of charge at the end of a charging process. This is only achievable by integrating additional information obtained from BEV drivers, such as realistic/actual departure times (Isaksson & Fagerholt, 2012). A charging process, for instance, can only be time-shifted and efficiently managed if departure and/or parking times are available for planning charging schedules. Hence, the success of smart charging systems relies on the willingness (Garcia-Villalobos, Zamora, San Martin, Asensio & Aperribay, 2014) of BEV drivers when charging their vehicles. Until now, research mainly has focused on the technical development of such systems and their relevance for grid stability with sparse consideration of the user perspective on smart charging systems and their perceived suitability for daily life. Testing a prototype system in real-life is an essential step in user-centred design and was realized in the present research. The objective was to gather users' real-life experiences with a prototype of a smart charging system and investigate changes in the evaluation of the system while using it.

2 METHOD

In a field study that was split into two 5-month periods, 20 BEV drivers (18 men, 2 women) compared conventional, uncontrolled BEV charging (UC) with controlled charging (CC) at home in daily routine. The field study took place in the metropolitan area of Berlin and was set up within the research project "Gesteuertes Laden V3.0" which was funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. The timeline of data collection is depicted in Figure 1. For the present contribution, data collected after experiencing regularly BEV charging (Baseline) for 4 and respectively 8 weeks (T0) and after testing 'controlled charging' (CC) for several weeks (T1) were analysed.

2.1 Implemented smart charging system

The implemented prototype of a smart charging system aimed to maximize the potential of BEVs for secondary reserve power. Each test vehicle (BMW ActiveE) was equipped with smart charging technology. A smart charging box with internet connection was installed in each of the 20 households.

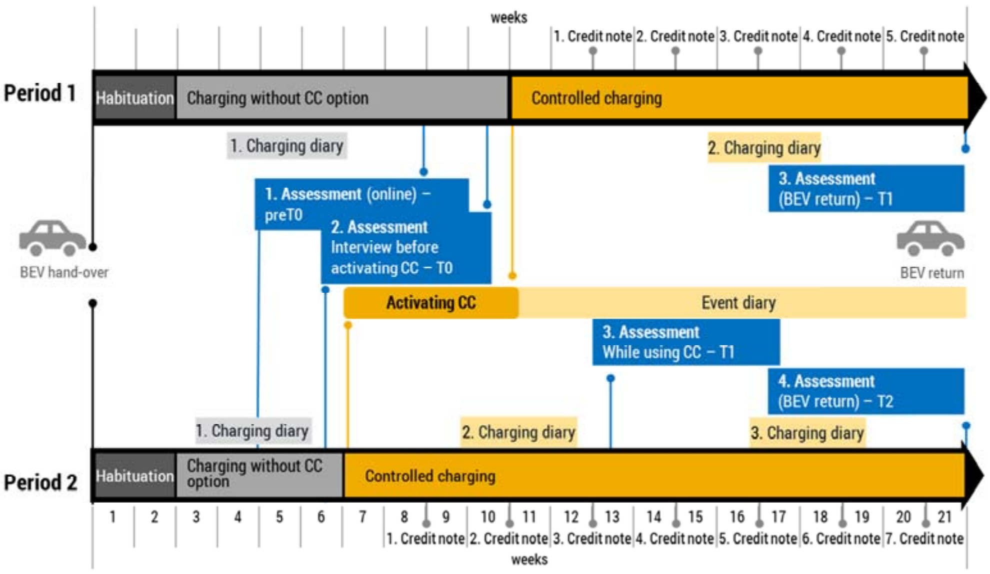

Fig. 1 Timeline of the two field study periods.

During the 'controlled charging' phase, users could set departure times, the battery level needed as safety buffer (≤ 45%) that will be charged as fast as possible and a minimum battery level (≥ 50%) that should be guaranteed at the departure time via smartphone application. The application also served as remote access to the vehicle, providing information (e.g., state of charge, charging process on/off, energy consumed). Between the two study periods, the application was further developed by, for instance, implementing push-notifications (e.g., BEV is fully charged). As a consequence, data on the usability of the application was not pooled for analyses.

A reward system was implemented for charging processes with the CC mode in order to motivate participants to plug-in their BEV as long as possible and to choose small safety buffers as well as low levels of the 'minimum battery level'. Participants were rewarded with points (max. 40 points per charging event) that were displayed in the smartphone application. Points were converted into Euros every 2 weeks (1 point = 2 Euro cents).

2.2 Questionnaire & Interview

Questionnaires and interviews were used to investigate users' experiences, expectations, attitudes, charging behaviour, (future) willingness to use such a system as well as suggestions for improvement. Within questionnaires at T0 and T1, an adapted version of the 12-item unidimensional scale for trust in automated systems by Jian, Bisantz and Drury (2000) was included in order to assess trust in the smart charging system. Thereby, the 7-point Likert scale ranging from 1 (fully disagree) to 7 (fully agree) was maintained. Furthermore, participants rated perceived effectiveness, acceptability, suitability for daily life (3 items) as well as their willingness to use CC (WTuse) in the project and afterwards (for details see Schmalfuß et al., 2015). If not stated differently a 6-point Likert scale ranging from 1 (completely disagree) to 6 (completely agree) was utilized. At both points of data collection, participants filled in an open ended question on the average number of charging events the participant initiated each week. Only at T1, the number of controlled as well as uncontrolled charging (UC) events was assessed and participants rated different reasons for not using CC (e.g., technical problems). At T1, the usability of the application was assessed using the ISONORM 9241/10 questionnaire (Prümper & Anft, 1993) including a set of 35 semantic differentials that covered 7 different dimensions such as suitability for learning (see Figure 2). Participants rated the items on a 7-point scale ranging from "---" to "+++".

In the semi-structured interview at T1, participants were asked to summarize their experiences and make suggestions for improvements.

2.3 Participants

In sum, a sample of 20 users (18 men, 2 women) tested the smart charging system in a private household setting. The sample was on average 49 years old (Min = 32, Max = 61) and well educated (i.e., 14 held a university degree). All users had at least one additional car in their household, 12 of the 20 households had even two or more additional cars available, but 2 households used only the BEV within the study period.

3 RESULTS

Questionnaire data was analysed using t-tests for dependent samples. Responses to interview questions were recorded, transcribed verbatim and then coded according to thematic analyses (Braun & Clarke, 2006), using the MAXQDA 11 (VERBI Software, 2014). The number of participants who made a statement that fit in one sub-category (n) was reported.

3.1 Questionnaire results

Users evaluated the system as trustworthy, rather suitable for daily life, (rather) acceptable as well as effective in improving the German energy supply before testing it and stated to be willing to use the system (WTuse) within the project (Table 1). Between the two points of data collection no significant differences in evaluation of the smart charging system were found except for suitability for daily life (Table 1). Although the evaluated suitability for daily life decreased; it was still on a positive level at T1.

Table 1: Evaluation of the smart charging system at T0 and T1.

Assessed concepts	**T0** *M* (*SD*)	**T1** *M* (*SD*)	***p***	**effect size**
Trust [7LS, c]	5.6 (0.7)	5.4 (1.0)	.287	.37
Suitability for daily life [6LS, c]	4.4 (1.0)	3.9 (1.1)	.044	.72
Effectiveness [6LS, d]	4.9 (0.9)	4.5 (1.4)	.299	-.23
Acceptability [6LS, d]	4.6 (0.9)	4.2 (1.5)	.357	-.21
WTuse in the project [6LS, d]	5.6 (0.6)	5.4 (0.8)	.218	-.28

Assessed concepts	**T0** ***M* (*SD*)**	**T1** ***M* (*SD*)**	***p***	**effect size**
WTuse beyond the project [6LS, d]	5.0 (1.0)	5.3 (0.9)	.244	-.26

Note: n = 20; c = t-test and effect size d were calculated; d = Wilcoxon test and effect size r were calculated. 6LS = 6-point Likert scale, 7LS = 7-point Likert Scale

At T1, participants stated they had charged on average 6.2 times a week (SD = 2.0) and they had chosen in over 80% of the charging events the CC option within the testing period. The average number of charging events at T0 (M = 5.4, SD = 1.8) was not significantly lower (p = .132, d = -.47). The three reasons for not using the CC mode with the highest level of approval were ‘no access to CC’ at the charging station’ (M = 4.3, SD = 1.9), ‘technical problems’ (M = 3.9, SD = 2.1) and ‘make sure to have a fully charged battery at departure’ (M = 4.3, SD = 1.9). Rather disagreement was found for the statements that they did not use CC, because they ‘charged in times that were not rewarded’ (M = 2.8, SD = 2.1) or that the effort in making settings was too high (M = 2.1, SD = 1.4).

The implemented smartphone application satisfied the users in terms of usability and got an average score in the ISONORM 9241/10 questionnaire (1996) of 1.5 (SD = 0.7, period 1) and 1.4 (SD = 0.8, period 2) respectively which outreaches the minimum score of 1 for satisfying applications.

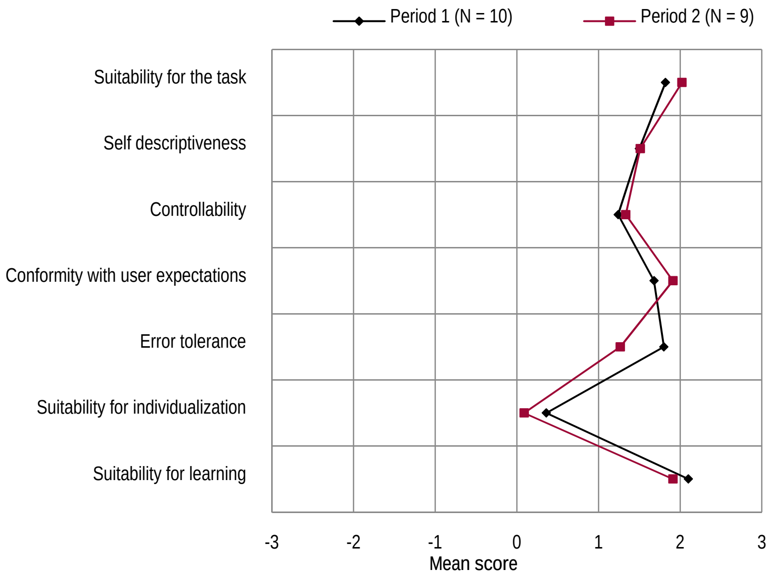

Fig. 2 Mean scores of the different scales of the ISONORM 9241/10 questionnaire (Prümper & Anft, 1993)

3.2 Interview results

Participants' reports of their experiences were quite differently. 15 of the 20 participants made positive statements about the smart charging system, for instance, they favored the concept and its implementation (e.g., "Great, it was fun. Everything worked without any problems.", A01)

Three participants stated that they had not made negative experiences, but the system itself, the requirements and their personal needs did not match (e.g., "It is not usable. If I had a battery with a range of 200–300 km I could use CC efficiently. […] Especially, charging takes ages... even with the wallbox 7 hours. [...] the concept is good.", A06)

Contrary to these findings, 13 of the 20 participants mentioned negative aspects in their experience reports. Eight participants reported problems while charging (e.g., unreliability of the system). Four participants reported negative experiences with the system as a whole (i.e., needs further development, e.g., "It is a nice thing. In my opinion, there has to be further development. It should be more stable. But in general, I support the concept.", A04) or the application

(i.e., need for an additional advice, e.g., "…that I had the application only for one advice, normally I would have it on different devices like my personal computer, tablet, smartphone...", A03)

Some participants criticized the lower flexibility when using smart charging (i.e., reduced available range; n = 3) and two participants expressed the need for more flexible charging times. Three participants made negative statements about the reward system (i.e., financial savings are too low, e.g. "In the end, I stopped using CC because savings were minimal and I did not see this as sufficient motivation to use CC… it is laborious.", A10)

Three participants reported that they did not "experience" a need for regulation. Specifically, when unplugging, they did not observe that the range exceeded the chosen minimum range ("I had chosen 80% as minimum, but it was seldom that the state of charge was over 80% in the morning.", A10). It is possible that minimum range was not exceeded although the BEV had served as regulatory instrument during the charging process.

Participants' answers regarding future requirements showed that the system needs further improvement in server/connection stability (n = 9) and therefore reliability. Charging duration should be reduced (n = 6) and the flexibility of rewarded charging times should be enhanced (n = 5). The reward system was another aspect mentioned for improvements; higher profitability was requested (n = 4). In the opinion of some users, future systems might also integrate innovative technologies such as vehicle-to-grid (n = 3) or inductive charging (n = 1). Additionally, push-up notifications in cases of system failures etc. (n = 6) and an additional user access (e.g., second device, n = 2) was desired by several users.

4 DISCUSSION AND CONCLUSION

A field test is a good opportunity to investigate users' real-life experiences with a smart charging system with high user involvement as such a system has not been established yet. However, it is typical for a field test that researchers cannot control for surrounding conditions.

Reported experiences within the interviews ranged from “awful” to “great” and from “poorly developed” to “worked without any problems”, but many participants integrated CC successfully into their daily routine and experienced the system positively. Others were less positive about the system and emphasized the need for further development. Valuable indications in order to increase consumer acceptance of smart charging systems in future ecomobility systems were gained. Interview results show that future systems need to be further developed, especially in terms of reliability. In addition, shorter charging durations or a fast charging option should be realized in order to address the users’ requirements of more flexibility of charging processes and freedom of movement. Further potential for improvement was found for the reward system (i.e., higher profitability) and the application (i.e. more information about BEV and state of charge), although its usability scores are already satisfying. Technical improvements, such as the integration of vehicle-to-grid or providing a second interface (e.g., additional smartphone login, online portal) might have a positive effect on the user experience and suitability for daily life.

Regarding the charging behaviour, questionnaire results showed that CC was extensively used by the sample (approximately 80% of charging events) and indicate that the percentage of ‘controlled’ charging processes could be enhanced when providing the CC option on more or even all charging stations and reduce technical problems. In sum, usage rates also indicate that participants accepted CC.

To conclude, results of this field study show that a smart charging system like the implemented prototype is useable and acceptable in daily routine. Furthermore, they provide valuable indications for the further user-centered design of smart charging systems in order to increase consumer acceptance of smart charging systems in ecomobility systems. Reliability needs to be increased, more access points to the smart charging systems provided and the BEV technology (e.g., battery capacity) enhanced.

5 ACKNOWLEDGMENTS

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MINIATURE TRAFFIC DEMONSTRATOR WITH DRIVING SIMULATOR

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ABSTRACT: Driving simulators and traffic simulations can potentially be greatly advantageous for applications in research and development, training and assessment. In particular, these systems are safe, and their respective experiments are inexpensive. Such simulations offer very flexible setup conditions, allowing for various scenarios to be studied, and several parameters and factors to be easily recorded. Since the early 2000's, the Institute of Dynamic and Vibrations (IDS) at the Technische Universität Braunschweig has developed various paradigms for a small-scale simulation, focusing on the drivers' behavior. This paper (and presentation) describes some aspects of the development and implementation of the small-scale traffic demonstrator, with car driving simulator components. The small-scale simulation vehicles can be operated by human drivers, as well as by virtual drivers (mathematical description of the driver behavior realized in program code). These virtual drivers are able to directly drive the moveable cars in the same ways as human drivers in the laboratory. In both cases, the behavior of drivers during specified difficult driving situations can be observed and studied. The external driving simulators or driver models can be linked by Internet. The IDS car driving simulator will be presented with regard to the visual system, to the driver interface, to the modeling and realizes acoustic and haptic information for the human driver to complete the driving illusion.

Key words: *driver's behavior, driving simulator, traffic laboratory, driver model, microscopic simulation.*

1 INTRODUCTION

Increase in number of vehicles and volume of transportation, despite the growth of length of roads creates many unwanted effects. On the example of road congestion (congestion cars) easily demonstrate the instability of traffic flow and the diversity. Mobility of the population, as an inseparable part of modern society, accompanied by unpredictable behavior of drivers and requires more research aimed at solving transportation problems.

Many problems, posed on the traffic, force the development of simulation. Many questions can be resolved with the directly use of an experiment, but it requires a significant investment of money, time, and may be in many cases unsafe for road users.

Completely another way for traffic simulation is a computer simulation. This part due to significant advances in computer technology and lower cost of equipment found special popularity in the scientific world. Simulation has considerable potential for many applications in a number of fields, including education and scientific research, medicine and industry.

Simulation help us not only describe the behavior of real systems, but also help forecasting the state of real and not yet implemented systems, to determine the potential of the system and to optimize it. These types of simulations in a field of traffic are based on models of realistic traffic scenarios trying to give general answers on effects, for example, of growing traffic densities, environment and possibilities of global traffic control [1].

More importantly is an understanding and a potential for human factors, which have crucial role in vehicle guidance. Errors and misconduct of the driver inevitably lead to traffic accidents. With real driver and simulations environment safety can be better understood. Any variation and repeatability of the driving situation in this form of simulation increase control. In any case, it is not a threat to other road users.

Modern driver assistance systems and driver information systems brings more safety [2]. In the development of driver information systems and driver assistance systems numerous road tests with human subjects are usually required. Become a real subject replaced by a driver model and dealing with simulated environments, so this saves a lot of time and money. Moreover, interactions of the road users can be better analyzed. A driving behavior and misbehavior can be identified and predicted. Another major research issue is the nature of participant interaction with each other.

Finally, simulators are usually included as a real car, so that can be research not only technology itself, but also ergonomics. Scientific work issues such as the design and evaluation of user interfaces are often handled empirically. Many ergonomists can report from personal experience that the cost associated subject’s studies mostly as a right - and prove time-consuming.

2 PUBLICATIONS REVIEW

Depending on the size of scenario for developments the simulation models are more or less realistic images of a whole country, a region or some roads. In modeling of transport processes can be found different models usually from macroscopic to microscopic levels.

Different models of the macroscopic level are published in [2], [3], [4].

The classical macroscopic model does not deal with the individual elements (road users). At the macroscopic level traffic flows are usually treated as physical flows (as hydro or gas dynamics).

Microscopic simulation considering each element (vehicle, pedestrians, etc.). Microscopic models are also described in [2], [3], [4]. It should be noted that at a microscopic simulation is very important to have the possibility of integrating the real driver [5], [6].

Using a car simulator expands the use of environment simulation and using real drivers [7]. The world already has hundreds of different simulators from very simple to complex dynamic structures. Car simulators distinguished by the presence of various basic elements for driving vehicle (steering wheel, pedals, etc.), a variety of organizations visual field of view, acoustic channel (stereo, surround sound), having a dynamic platform, etc.

However, all driver simulators have one thing in common - the driver does not perceive the danger of artificially created as when driving a real car in the real world. A small-scale traffic laboratory by IDS at the Carolo-Wilhelmina Braunschweig University of Technologie will show difference, will demonstrate how it can be organized and how it works.

3 OBJECTIVE AND TASK

The aim of this work is to create a microscopic simulation laboratory with the ability to use real drivers while approaching the real driver perception of danger. The next important decision is using not only one but several drivers simultaneously. In this case is important to build a possibility to switch many driver simulators at the same time on one place with the same condition. Moreover, the ability to connect to a lab from the internet should bring a possibility to demonstration driver’s models.

To perform this task, first of all, we need to identify important factors of perception by the driver, to determine their possible impact on driving tactics, an analysis of existing elements in the laboratory, to create the necessary components for a real driver for the laboratory as a whole, using the possible future research questions investigations.

Interactive simulation provides the opportunity to study revealed behaviour by simulation within a controlled environment and to find correlations with their own research.

4 LABORATORY MICROSCOPIC SIMULATION

In the laboratory small-scale simulation vehicles are defined as models of cars made in 1:10 scale (see Fig. 1, left). Trees, road, road signs and other objects are also made in 1:10 scale. Cars controlled by computers as by using a mathematical model of the driver and using the car simulator (Fig. 1, right).

Fig. 1 Traffic laboratory (left) with driving simulator (right).

Car simulator is the front part of the real car with all factory components inside the cabin, the projector for video transmission from the controlled vehicle in the laboratory microscopic modeling of transport, as well as special machine internal funds (sensors, actuators) for communication processing and output of information. Special factor in this scheme is the integration of a real driver in the simulator.

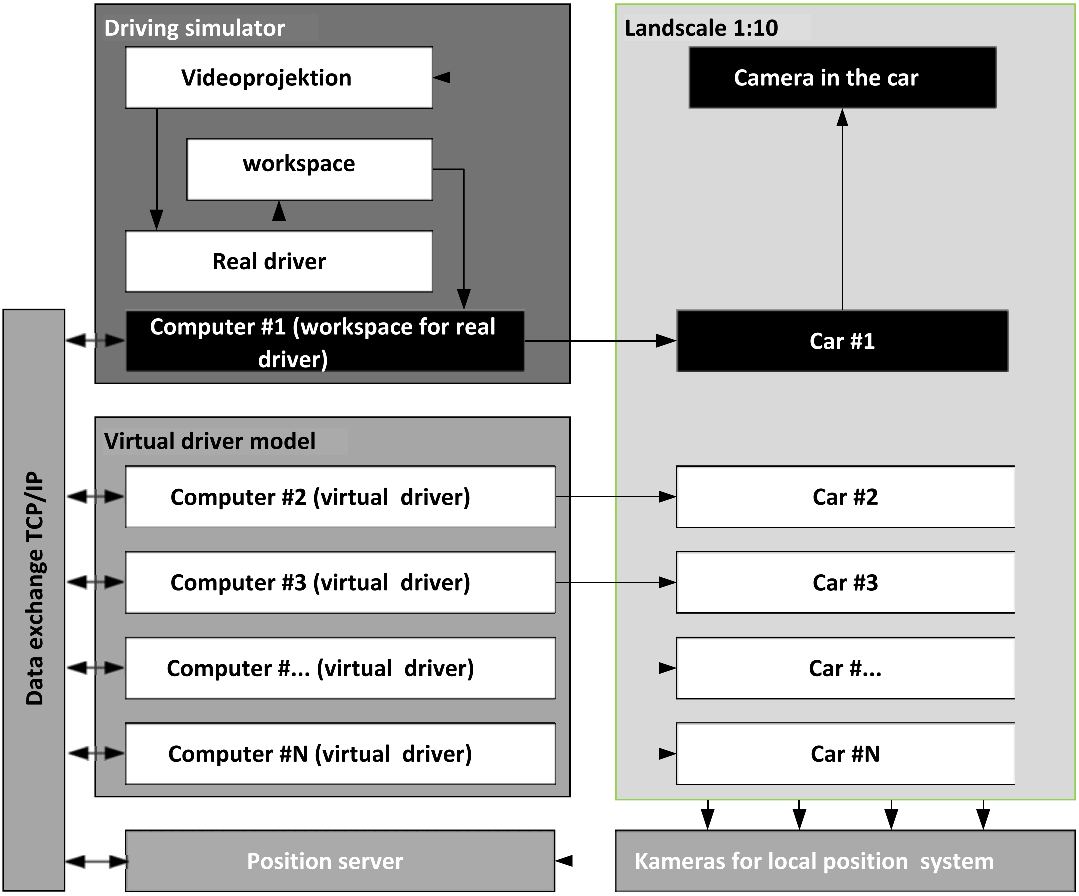

Fig. 2 In Laboratory Communication.

After analyzing a number of factors that affect the human perception of information and analysis of the existing equipment in the laboratory have been significant transformations, as in the automobile simulator and laboratory modeling of the transport medium.

5 TRANSFORMATION IN THE LABORATORY

About 90 % of the information the driver perceives visually. After a series of transformations finalized not only the visual channel to the peripheral vision, but also has been organized such as visual systems projecting information onto the windshield, information display as human-machine interface, built-in toolbar, and display system is implemented for the side mirrors and rear view mirrors. Fig.3 and 4 shows some examples about it.

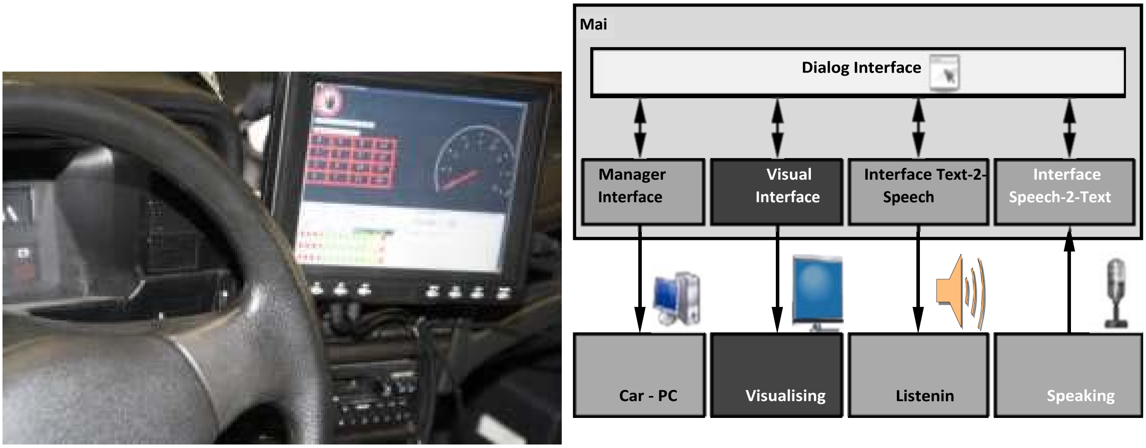

Fig. 3 Example Cockpit HMI.

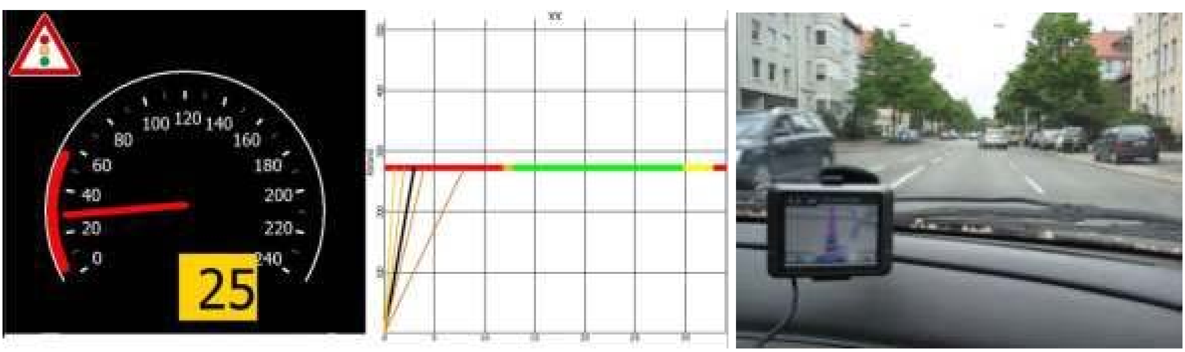

Fig. 4 Example Cockpit HMI as light traffic assistant.

For 360 Field of View has been used catodioptric lens. This feature allows gathering visual information in horizontal field of view with 360° - completely field for driver around the moving car.

Fig. 5 Example 360 Field of View for driver simulator.

After completions and improve visual channel was has been developed and implemented a sound module for car simulator [8]. Sound module allows you not only to create different signals and sound effects (from the wheel, engine, wind noise, etc.) but also to create other sounds of other road users in the three dimensional space for the driver and distribute them in accordance with the real source and the direction.

The next step in development driver simulator was a building force-feedback on power steering system. A reference steering torque provides to the driver a desired steering feeling. This system allows the adaptation of the steering feel to the current driving situation while experiment.

For a new design of cars has been designed a microcontroller based board. The analog and digital peripheral units allow to monitoring car behaviour and communicate with computer. As an example was implemented Raspberry Pi Board, which communication with a microcontroller was implemented with Inter-Integrated Circuit (Two-Wire- Interface). The Raspberry Pi lets us record data without fear.

But really important was integration of some drivers at the same time in experiment. A main point was a build a connection between micro-traffic laboratory and various driver simulators. Thus a completely new model of communication has been implemented which allows together several clients in the overall network and provide an opportunity for communication between multiple clients simultaneously. Fig. 6 will demonstrate this example

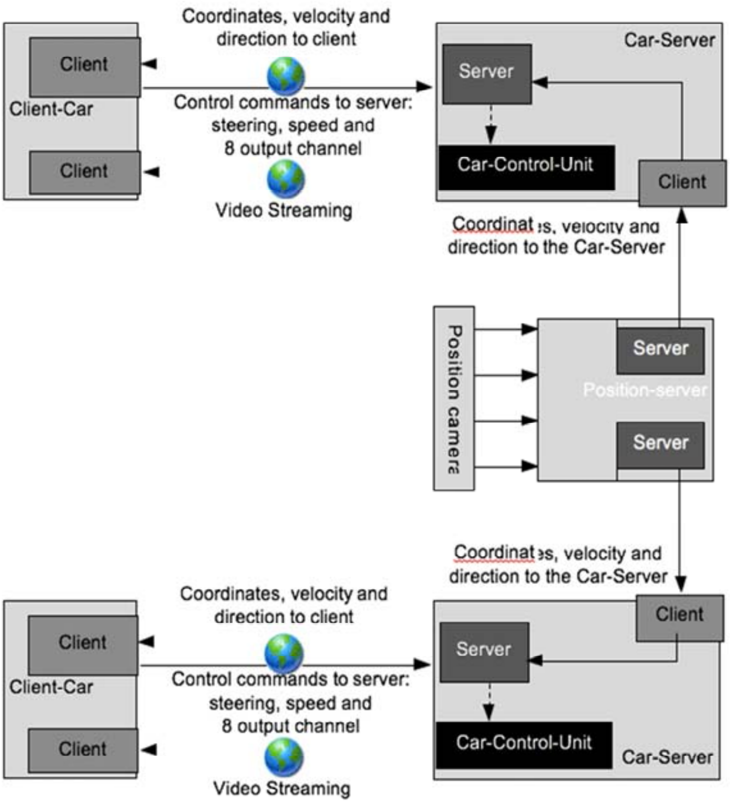

Fig. 5 In-the-World Communication

In the micro-traffic laboratory has been using a local position system, like a global position system. The accuracy of a localization system allows to determine the position of the car up to one centimeter, which, based on the normal system are about ten centimeters and exceeds the capabilities of the global navigation system localization. Determination the coordinates of a vehicle occurs via LEDs are arranged on the roof of the car and camera, which are mounted on the ceiling of the laboratory. The use of digital maps allows using mathematical models of drivers.

6 CONCLUSIONS

As a result of the creation and implementation has been developed the acoustic module, enhanced visual systems, force-feedback system for reality in the simulator. Study driver behavior under different conditions will allow reducing to a minimum the impact factor errors due to lack of visual, acoustic or tactile information. The simulator provides a good tool for developer driver information and assistance systems that help the driver to control the vehicle and has recently become an integral part of modern cars. Such systems help to increase the level of safety in the vehicle and reduce the number of accidents and their consequences.

In the laboratory, some of the models are implemented as virtual drivers and integrated real driver. In both cases, it gives you the opportunity to observe and study the behavior of drivers in the implementation of certain difficult driving situations [7]. May further investigate the interaction of different mathematical models with the real driver's[10]. Car sensors and other electronic devices enable us to record measured data directly during the experiment. In a laboratory has been developed for in-laboratory experimentation to gather data for estimating and calibration predictive models of driver behaviour under condition of real-time information. In conjunction with the subjective opinion of the drivers it gives an opportunity to find a correlation to improve assistance systems.

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