ELECTRIC VEHICLES AS A SOLUTION FOR GREEN DRIVING IN THE FUTURE? A FIELD STUDY EXAMINING THE USER ACCEPTANCE OF ELECTRIC VEHICLES

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ABSTRACT: Facing the growing CO2-emmission, alternative means of transportation such as electric vehicles (EVs) arise. Aim of the current study is to examine the user acceptance and the impact of EVs on user's daily mobility behavior using psychologically founded methods. For this purpose a large scale field study with two periods of six month of EV use is adjusted in the metropolitan area of Berlin. The methodology applied three times during each usage-period includes in depth interviews, questionnaires, travel and charging diaries as well as a conjoint analysis. The paper gives an overview over the variety of methods used in the study and outlines preliminary results indicating that users have a positive attitude towards EVs and a good acceptance of the new technology.

1 INTRODUCTION

Reduction of greenhouse gas emissions and the expansion of renewable energies are crucial challenges for the future. These topics arise from the decreasing accessibility of energy resources, which are decisive for the maintenance of mobility. As one of the key solutions to address the growing CO2-emissions, EVs charged with renewable energy sources have been discussed controversially. Especially for metropolitan areas these vehicles appear to be appropriate as the distances travelled are predictable and building new infrastructure (e.g. charging stations) can be accomplished efficiently. Nevertheless barriers in technology such as price and size of the batteries as well as the limited range of EVs are issues which hindered overall acceptance and therefore large-scale market launch in the past. Beside the public attention and the presence of EVs in the media, the electrification approach is also an issue of the German Federal Government: In 2009 an initiative to promote electric mobility has been published. Sustainable transportation, development of electric vehicles and research on acceptance are also part of this program.

The objective of the current one-year field study is to develop, adjust and apply psychologically founded methods to assess the acceptance of EVs in everyday use. Based on these methods. it will be possible to identify influencing factors on the acceptance of EVs and line out changes e.g. in attitudes or behavior of the participants during the trial test. In this context one crucial topic is, whether EVs meet the mobility needs of the users and how user adapt to EVs. Mobility patterns are an important issue as planning in particular plays an important role among EV-users due to the limited range and the extended charging duration. This article focusses on the methodology used in the present

field study and outlines first results and implications found throughout the first two points of data collection.

In the scientific literature there is only few published research examining the acceptance of EVs. Furthermore surveys without EV trials are often criticized as respondents are usually not familiar with EVs and thus do not have enough knowledge and experience to assess the technology [1]. Against this background, the current field study offering hands-on experience for the users is of great importance. The application of a longitudinal research design allows drawing valid conclusions about changes in attitudes and behavior. Nevertheless comparisons between subjects in the degree of change can also be made and linked to certain attitudes or personality traits.

2 METHODS

The current large scale field study is split into two periods of six months each with a different sample of 40 users with an EV in their household. Additionally 10 EVs are integrated in a so called 'fleet setting'. However, methods and results of the fleet setting will be reported elsewhere. During each period of the study there are three points of data collection: First before participants receive their car, after three months of usage and when returning the car. Repetitive measuring enables the detection of changes in attitudes, experience or behavior.

To paint a valid picture of advantages and challenges of EVs a number of methods are employed at each phase of data collection: There are subjective data from structured in depth interviews, questionnaires, travel and charging diaries. The methodology incorporates also experimental elements such as a choice-based conjoint analysis to measure preferences and a trip decision task dealing with the limited range. The subjective data are supplemented by objective data collected via data loggers in the car. These loggers continuously record parameters like mileage, speed, charging cycles and trip length. The following section gives a detailed description of the subjective methods implemented.

2.1 Research methodology

2.1.1 Questionnaires

In order to get quantifiable data concerning the acceptance of EVs and the adaptation process, questionnaires are administered at three times during the period of EV use: The first one addressed mainly expectations and opinions about EVs and had been sent to the participants before they got the vehicle to establish a baseline measurement. The questionnaires applied after three and six month driving the EV focussed on the experience with EVs. Whenever reasonable established standardized instruments have been used to measure certain aspects. An example is the van der Laan acceptance scale [2], which assesses the system acceptance of new technology on two dimensions, a usefulness scale and a satisfying scale.

The following list provides an overview of topics addressed in the questionnaires:

- attitudes towards EVs
- aspects influencing the acceptance according to Ajzen‘s Theory of planned Behavior [3]
- purchase intentions
- mobility needs and mobility behavior
- driving behavior and eco driving
- acceptance and experience of EV-specific features, especially regeneration function (for futher information see [4]) or limited range
- critical situations due to the low noise of the EV but also due to electricity
- usability of the EV [5]
- evaluation and requirements analysis of EV-specific displays (for further information see [6])
- charging the battery
- usage and acceptance of public charging infrastructure
- attitudes towards renewable energy
- personal characteristics like affinity for technological innovations [7], environmental concerns [8] or need for change [9]

2.1.2 Interviews

When participants were selected to take part in the study, they were interviewed by phone. The interview manual basically contained questions concerning the knowledge of EV issues, environmental topics and the person’s motivation to participate in the study.

Further more several face to face interviews were conducted : The first one right before the participants drove the vehicle for the first time. Of special interest was to discuss expectations and concerns of the participants about the vehicle, charging the batteries and the usage of the charging infrastructure. Further interviews were accomplished after three and six month of EV use in terms of standardized questions, predominantly dealing with specific vehicle and charging experiences.

All interviews were audio taped and transcribed. By analyzing the interview data, mental models of the participants about relevant topics could be qualitatively identified. Examining a new technology such as EVs, interviews are an essential method to get crucial and sophisticated knowledge about the object of research [10].

2.1.3 Think aloud

While driving the EV for the first time, participants were asked to verbalize their thoughts over a certain period of time of the test drive. Through recording the immediate interaction with the vehicle rational thoughts as well as memory bias can be avoided. The think aloud protocol is a well established method to measure system usability in a qualitative manner [11]. Besides analyzing the audio taped protocols provides information about first impression of the vehicle and its handling.

2.1.4 Experimental tasks

Conjoint analysis

Refering to Luce and Tukey [12], conjoint analysis is a valuable method measuring what combination of a limited number of attributes is most influential on respondent choice or decision making. In order to assess preferences, which are also crucial for the acceptance of EVs, a choice based conjoint analysis was implemented at the three points of data collection during the study. Respondents were instructed to choose an appropriate EV out of three presented alternatives or to refuse all in each of the 15 trials. The different versions were described through four aspects whose specifications were randomly assigned by the computer. The factors taken into account were determined by an expert rating.

The variables and their characteristics were as follows:

- range (100 km, 200 km, 300 km, 400km)
- CO2-emissions (5 g/km, 50 g/km, 90 g/km, 130 g/km)
- fully charging duration (½ hr, 4 hrs, 8 hrs, 12 hrs)
- monthly leasing rate (200€, 400€, 600€, 800€)

The applied procedure allows the identification of the attached importance of the relevant variables and trade-offs. Conjoint analysis is a well established instrument for consumer research and has been employed in earlier studies concerning EV purchasing intentions in order to identify the relative importance of EV characteristics [13].

Trip decision task

The trip decision task deals with the limited range of electric cars and has the aim to quantify the comfortable range and subjective buffers set by the users. Given a certain trip with a distance of 60 km that should be driven, participants were asked to indicate whether they would do the trip and to what extent they would feel comfortable while driving. Whereas trip conditions and trip length were kept constant, the remaining range (range display status) was varied in intervals of 5 km. Through an iterative process the level of comfortable range is narrowed down to an accessible span. This method offers information whether there are concerns about the limited range and at which point they arise. Furthermore merging personal characteristics with results of the trip decision task also provides valuable information [14].

2.1.5 Travel and Charging Diaries

Similar to other EV studies, the participants were asked to fill in a travel diary in order to log their daily mobility behavior over a period of one week. The person-based diary collects data including trip length, means of transportation, purpose of trips as well as departure and arrival times for each trip. As most of the other instruments the travel diary is administered three times during the study : First before EV use, in the middle and at the end of the period of EV use. Taking all means of transportation into account the travel diary provides valuable information in addition to the data collected by the data logger. Furthermore the

basline measurement allows comparisons in mobility patterns that may arise during the period of EV-use as well as between an EV compared to the former conventional car. Travel diaries are well established in transportation research and have also been used in past studies on EVs [1].

During the period of EV use additional to the travel diary a charging diary is employed. It records data concerning charging the vehicle including charging location, state of charge at the beginning and in the end of the charging process and motives for charging. The information collected via the charging diary gives the opprtunity to draw conclusions regarding charging patterns and the potential of timed charging, a process developed by the energy provider in order to utilize the potential of renewable energy.

2.2 Electric Vehicles

The vehicle used in the study is a standard MINI Cooper converted to a battery powered vehicle with a lithium ion battery pack. Featured with 150 kW power and a 220 Nm torque the two-passenger vehicle is capable of reaching a top speed of 152 km/h. The vehicle's regenerative braking system transfers kinetic energy from the momentum back into the battery. This causes a deceleration whenever the driver takes the foot off the gas. Participants have the opportunity to recharge their EV at a wallbox installed at home or at one of the public charging stations spread over the city of Berlin. A fully charge of an empty battery takes about four hours (32 Ampere fuse). The range achieved under ideal conditions is 250 km on a single charge.

2.3 Participants

More than 700 people applied for the first period of EV use via an online application that included numerous questions in order to check whether candidates fulfill certain criteria. Thus requirements for participants were living in the metropolitan area of Berlin, where the field trial takes place, willingness to take part in scientific surveys, willingness to pay the monthly leasing rate, available garaging and suitable connection for power supply and further conditions. After selecting the applicants who fulfilled the requirements (N = 161), the sample (N = 40) could be selected according to scientific creteria. For that purpose several questions about demographics and prospective car use had been asked in the online screener. There were two main selection creteria : The first factor included the expected kilometers driven with the EV, whereas half of the participants would drive more than 250 km with the car in one week or less respectively. The second factor defined the number of cars in the household according to the hybrid household hypothesis [11]: Either the EV would be the only car in the household or the EV would be integrated in the household’s fleet of vehicles (hybrid households). Based on the fact that only few applicants expected to be a single car household, the sample includes 31 hybrid and 9 EV households. Additional factors like age, gender, education and previous EV experience with EVs or cars with hybrid electric drive were considered. Characteristics of the sample are given in Table 1.

During the first three month of EV-usage there was a drop out (N = 1) because of technical problems.

Table.1. Sample characteristics (N = 40)

Characteristic		Breakdown
Gender	male	82.5 %
	female	17.5 %
Education	university degree	75 %
	vocational school	7.5 %
	apprendiceship	12.5 %
	graduation	2.5 %
Previous experience with electric drive	no	75 %
	yes	25 %
Children under 18 in the household	no	57 %
	yes	43 %
	μ	Σ
Age (years)	48.63	8.758

3 RESULTS

Motivation for taking part in the study

Data from the questionnaire applied before EV use indicate the following most important reasons for taking part in the study (M > 5.00 at a 6-point likert scale): Users want to test something new and innovative, they want to support the development of a new technology, they are very interested in technology and they think that the electric drive is the technology of the future. Besides they attend to contribute to environmental protection and because they want intependence from gasoline. Nevertheless one of the most important motives participating in the study is testing whether EVs are an alternative to conventional cars.

The motive participating due to high interest in technology is supplemented by a high mean score in affinity for technology. And taking part because of contribution of environmental protection as one important motive matches the relatively strong emergence of environmental concerns.

Acceptance and attitudes towards EVs

First results show that attitudes towards EVs measured via a 6-point likert scale are mainly positive on average. Basically attitudes remain positive during the first three months of EV use : There is even a tendency towards a more positive assessment.

When asked for the acceptance of the EV as a new technology via a standardized acceptance scale [2], user's response after a three months period is also positive : On a continuum ranging from -2 to 2 the usefulness as the first factor of the scale reaches a score of M= 1.4 (SD = .452), indicating well rated practical aspects. Data concerning the second aspect, satisfaction, show similar results : With M= 1.63 (SD = .476) users assess the EV as highly satisfying.

Range and mobility needs

Before receiving the car, the majority of the participants expected to be constrained by the limited range. Survey data after three months of EV use indicate that for more than 94.3 % of the users a range of 140 to 160 km is sufficient for everyday needs, especially within the urban area of Berlin. As users estimate, the mean maximum range driven with the EV is 150 km. When asked for target values for range, participants report less than 100 km as insufficient, 200 km and above as sufficient and 250 km as optimal range.

67.7 % of the users rate the flexibility with the electric car as high as with a conventional vehicle. Further survey data indicate that about 80% of daily trips could be done with the electric car. If cargo and passenger space was not limited due to the size of the battery, participants expect to be able to do more than 90 % of the trips with the EV. Similar results can be seen analyzing the travel diary data: Only 14 % of the total number of trips driven in one week could not be done by the EV due to its restrictions, e.g. cargo space.

Purchase intentions

Preliminary results show high purchase intentions for EVs among the users after three months of EV use: About 97 % of the participants indicate that they want to drive an EV in the future. Based on the experience with the EV, 75 % of the users report to involve more eco-related issues when thinking about future car purchase. More than 95 % of the users believe that renewable energy should be used for charging EVs. Only 33 % of the users approve of nuclear energy to charge EVs, solely 8 % would accept to charge with energy from coal-fired power plants.

4 DISCUSSION

In the present study an extensive package of methods is applied to take all relevant issues into account, which affect the acceptance and suitability of EVs for everyday mobility. The sample might not be representative for the whole population due to self-selecting processes and other limiting factors (e.g. environmental consciousness, income, education): Nevertheless it provides a good insight into preferences and attitudes of the target group, which is interested in progressive technologies such as EVs. In order to generalize the results a validation with a larger, less selected sample is needed.

Preliminary results of the first two points of data collection in this study indicate that there appears to be a high acceptance for EVs as well as a positive attitude towards EVs among the users. Concerns about the limited range expressed by the users at the beginning of the study have not become real after three months. This could be due to the fact that the study takes place in a metropolitan area where mean length of trips is shorter anyways. Besides most participants have a second car in their fleet to compensate the limited range of the EV. Furthermore first results reveal that participants are very interested in the sustainable technology and show high willingness to use EVs in the future, but suitable business concepts are to be developed. As expected, ecological aspects such as CO2-emissions and the utilization of renewable energy play an important role in the evaluation of EVs.

5 ACKNOWLEDGMENTS

This study is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Software for conducting the conjoint analysis was kindly provided by Sawthooth Software, Inc.

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