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Changing attitudes towards e-mobility by actively elaborating fast-charging technology

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ABSTRACT

Since electromobility (e-mobility) is a large field of innovation, it is crucial to examine new developments with potential users in mind. Therefore, we investigated the impact that new fast-charging technologies for electric vehicles (EV) have on ordinary people's assessment about the future prospects of e-mobility—which is an important prerequisite for increased attitudes towards e-mobility in general. First we let participants perform a typical charging process, where they were either introduced to the slower-operating, alternating current (AC) system or the fast-operating direct current (DC) system. In a second experiment we used the same procedure but instead of letting participants actively perform the charging process, they were only given written information about these charging technologies. Results show that participants' future estimation about EVs only rises when they actively charge an EV in the fast DC condition but not in the AC condition. General attitudes towards EVs increase independently of the AC or DC condition. None of these effects could be seen without active hands-on experience (second experiment). These indications imply the value of investing in fast-charging systems to induce more favorable judgments regarding the future prospect of EVs. The importance of letting people actively take part in the way e-mobility works will be discussed regarding the potentially improvement of participants' attitudes towards e-mobility.

1. Introduction and theoretical background

Germany's transportation sector was set to be revolutionized recently, according to the German chancellor Angela Merkel, by having one million electric vehicles (EVs) on Germany's roads by 2020. Given that the number of electric cars is only 18,948 in Germany as of January 1st, 2015 (Kraftfahrt-Bundesamt, 2015), it is obviously an ambitious aim of the German government; but considering the potential of these vehicles to reduce carbon dioxide emissions, they do present a promising ecological-sustainable transportation system solution (Holdway et al., 2010). A major reason for this low number of EVs is commonly seen in the hitherto low number of EV models on sale. Considering the prognosis in the market development roadmap proposed by experts from the German National Platform for Electromobility, the strongly-increasing number of EV sales required is expected to occur during the market ramp-up phase of 2014–2017 with 15 new EV models becoming available at the beginning of the phase through German automobile manufactures alone (Nationale Plattform Elektromobilität (NPE), 2012). EVs only have a chance of succeeding in the mass market if they meet customer expectations (Vilimek and Keinath, 2014); however a recent poll has revealed that public opinion on electromobility is still quite skeptical in Germany (e-mobility; Schwedes et al., 2013; Steinhilber et al., 2013). Most of the reservations about e-mobility were caused by the limited range of EVs (Franke et al., 2012b), high costs and (infrastructural) charging complications (Bayram et al., 2013; Jin et al., 2013; Kampker et al., 2012). All these factors taken together bear the possibility of discouraging potential users from seeing EVs as a positive future prospect and thus from interpreting EVs as a valuable alternative to conventional mobility concepts, which seems to be the ultimate psychological prerequisite for heating up the EV market. Several studies attest to the everyday requirements of EVs (Bunce et al., 2014; Vilimek et al., 2012), using a longer-term study design to demonstrate an increase in the acceptance of EVs (Labeye et al., 2013; Neumann et al., 2010). Therefore it seems rather difficult to assess potentials of changing ordinary people's attitudes towards EVs in a short period of time. The German National Platform for Electromobility advocates four key areas for increasing public awareness and improving public opinion (NPE, 2012): (1) communicate advantages and the everyday suitability of e-mobility, (2) emphasize the positive ecological impact of electric driving, (3) reduce operating costs and, finally, (4) improve the charging processes. The latest development in charging technology offers the possibility of charging EVs very quickly (see Table 1), which

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Table 1
Different charging modalities of EVs, the corresponding charging power in kW and typical approximate charging duration from a nearly empty up to a fully loaded battery (dependent on local electricity infrastructure and charging equipment).

Charging modality	Charging power	Duration
Standard AC charging (e.g. household socket)	3.7 kW	6–8 h
Wallbox AC charging	4.6 kW–7.4 kW	3–6 h
Fast DC charging	Up to 50 kW	0.5–1 h

may now permit the evaluation of proposed improvement caused by fast-charging technologies—one of the four key areas announced by the NPE (2012) to increase public awareness and improving public opinion. It is based on DC (direct current) supply with a high current strength of up to 50 kW, which enables the charging of an EV with a nearly empty battery to a capacity of 80% in less than 30 min—much faster than conventional AC charging technology which needs several hours for the same gain of battery energy (Botsford and Szczepanek, 2009). Additionally, the Technology Acceptance Model (Davis, 1989) as well as its extensions (Venkatesh and Davis, 2000) predict that the perceived usefulness of a new technology is one of the most important factors for technology acceptance (Legris et al., 2003). Therefore, we were interested whether the present 50 kW DC fast-charging stations are able to increase the perceived usefulness of e-mobility and might affect potential users' attitudes towards e-mobility and their assessment on the prospect of EVs.

Since the International Society of Automotive Engineers (SAE) and the European Automobile Manufacturers Association (ACEA) determined the combined charging system (CCS) as a standard for fast-charging facilities, an important impulse was set for the compatibility of EVs with public charging systems. It offers, therefore, an interesting opportunity to reply to typical concerns about the limited range and long-standing recharge cycles of EVs. As the adoption of innovations directly influences the productivity as well as the profit of countries and companies (Mairesse and Mohnen, 2002) it seems important to be able to predict those progressions for the future of e-mobility. With the Repeated Evaluation Technique (RET) introduced by Carbon and Leder (2005) – a method to capture the dynamic effects of innovations – we are able to examine the dynamic effects fast-charging has on the attitudes of potential users. Using the RET we conducted two experiments in which participants either actively experienced the charging technologies or only passively received pure information about these technologies. We predict that experiencing fast-charging will positively impact the perception towards e-mobility.

2. Experiment 1

In the first experiment we were interested in the impact that actively using the new DC-system would have on people's attitudes towards e-mobility and their assessment on the prospect of EVs becoming a major mobility concept in the future.

For a valid ecological design we simulated a typical charging process and designed a specific method that enables us to track changes in user attitude and assessments on e-mobility while interacting with the vehicle. The method we used was inspired by the Repeated Evaluation Technique (RET) by Carbon and Leder (2005) which enables the capturing of dynamic effects concerning innovative aspects of e.g. e-mobility, already employed by a series of experimental (Faerber et al., 2010) as well as psycho-physiological procedures (Carbon et al., 2008). By selectively familiarizing participants with either the conventional, slow-charging AC-system or the advanced, fast-charging DC-system, we were able to compare the different effects these two charging systems have on people's attitudes towards, and assessments on, e-mobility. In order to additionally have the ability to observe changes over time, participants were asked to fulfill a questionnaire before (t1) and after (t2) the charging process. Between these questionnaires, participants were interviewed in the car while the charging was in progress to a) let them experience the fast DC- or slow AC-charging process, b) get information about the spare time activities they would favor during a charging process and c) ask them about usability and safety perception with regard to the charging procedure.

2.1. Method

2.1.1. Participants

Forty-six men and sixteen women (total $n = 62$), ranging in age from 18 to 75 years ($M = 43.6$ years SD $= 14.8$), agreed to participate in our study. All participants were randomly chosen German visitors from the "BMW Welt" (Engl.: "BMW World"—a multi-functional customer experience and exhibition facility of the BMW Group, located in Munich, Germany). After the experiment, participants received a gift coupon valued at € 7.— in compensation to be redeemed at the nearby BMW Welt.

2.1.2. Apparatus and stimuli

The charging station we used in this experiment was from the Asea Brown Boveri (ABB) group laid out for the combined charging system (CCS). The BMW Group provided a BMW ActiveE conversion electric vehicle assembled with a 28 kWh battery and a range of approximately 160 km that was compatible with the CCS standard. To gain optimal experimental control we decided to use a simulation app on a white SONY Xperia Z Tablet that was mounted on the original charging station screen. This app was able to simulate a time-synchronized typical charging procedure for the AC as well as the DC condition. The tablet-PC as well as the implemented app was adjusted to the charging station in such a way that it was hardly distinguishable from the original, unmodified charging station in order to keep the scenario as realistic as possible—in fact, none of the participants noticed the mock-up quality of the employed setting.

2.1.3. Setting and procedure

The field experiment took place in front of the main gate of BMW Welt in Munich, Germany over 2 weeks in summer 2013 (from the end of July until the beginning of August) when a charging station from ABB group equipped with the CCS standard was installed.

Participants were accompanied to the testing site where they first read and signed their written consent. As shown in Fig. 1, participants then filled in the t1 questionnaire. In this questionnaire, participants answered questions concerning their socio-demographic details, attitudes towards EVs, assessment of the future prospects of EVs, innovativeness, environmental attitude and existing experience. All quantitative data were measured on a seven-point rating scale from 1 to 7 (1 = do not agree at all; 7 = do absolutely agree). The exact wording of the items we report here is listed under Appendix A.

In the elaboration phase, participants were first introduced to the set-up for charging the electric vehicle. Afterwards they were given additional information about the charging station and the duration of the charging process depending on whether they were in the slow (AC) or in the fast (DC) condition. In the AC condition participants were told it would take up to 6–8 h to fully charge the car, while in the DC condition people were told it would only take approximately 20 min to charge the almost empty battery up to 80% (see Table 1). Subsequently, participants were asked to start the charging procedure without further instruction from the experimenter. Participants connected the plug with the vehicle and started the process on the display. As described before, participants were made to think that the charging was proceeding for real. To make sure the scenario was trustworthy, participants were informed after the experiment about the simulation in a debriefing session and asked if they had noticed the modification at any time or had had doubts about whether this was a real charging procedure. None of the participants said they had noticed at any time that the procedure was only a simulation instead of a real charging process.