ADAPTING TO THE RANGE OF AN ELECTRIC VEHICLE – THE RELATION OF EXPERIENCE TO SUBJECTIVELY AVAILABLE MOBILITY RESOURCES

Thomas Franke, Peter Cocron, Franziska Bühler, Isabel Neumann, and Josef F. Krems

Cognitive & Engineering Psychology, Chemnitz University of Technology

Wilhelm-Raabe-Str. 43, 09120 Chemnitz, Germany

(thomas.franke, peter.cocron, franziska.buehler, isabel.neumann, josef.krems)@psychologie.tu-chemnitz.de

ABSTRACT: Range of electric vehicles has been identified as a major barrier for acceptance of electric mobility within studies with inexperienced potential users. However, results suggest that experienced users are able to successfully deal with, and thus, are often satisfied with available range. The relation of experience to the perceived fit of mobility needs and mobility resources and subjectively usable range was examined. Positive experience-related effects were found. A tendency for actively exploring the range of an electric vehicle was linked to more successful adaptation. In conclusion, skepticism about range or even range anxiety may be overcome by assisting potential users explore the fit between mobility needs and mobility resources.

Keywords: electric vehicle, range, field study, mobility needs, user experience.

1 INTRODUCTION

Range of electric vehicles has long been considered a major barrier in acceptance of electric mobility. Market experts as wells as inexperienced potential customers have evaluated the effects of low range resources of electric vehicles as a critical factor for users' purchase intentions and thus for the market success of electric mobility systems [1-3] However, existing data drawn from travel surveys [4, 5] and feedback from expert electric vehicle

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users [6, 7], show that electric vehicles should indeed easily meet most users' mobility needs.

One possible reason for the gap between subjective and objective mobility needs may be personal safety buffers; these buffers likely exist due to a lack of experience with electric vehicles, that is experience with short-range mobility, as well as to inaccurate conceptions of mobility needs [8]. In addition, it has been recently argued that only a certain share of nominal range is (subjectively) accessible to users and that this usable range depends on existing range skills of a driver [9, 10]. Consequently, novice users may have a lower subjectively accessible range than experienced users given the same objectively available range of an electric vehicle. Hence, experience and practice with an electric vehicle may explain the contradictory findings on range being a barrier for market success of electric vehicles to some extent.

There is a lack of published research on the effect of experience on the perception of range as a barrier in electric vehicle use. The main objective of the present research was to examine the relation of experience to the perceived fit of mobility needs and mobility resources, and to the usable, more specifically the comfortable, range that is available to each individual user. This research also examined whether or not experience was related to general evaluations of range as a barrier for market acceptance and if experience was related to a lower importance rating of range improvements for purchasing intentions.

2 METHOD

The present research was part of a large-scale electric vehicle field trial in the Berlin metropolitan area in Germany. Forty main users drove an electric vehicle for a 6-month period. In this longitudinal study, data was assessed at three time points: prior to receiving the electric vehicle (T0), after 3 months of driving (T1), and upon return of the electric vehicle (T2). These points of measurement represent relevant states in the adoption and experience-acquisition process. Structured interviews (approx. 7 h of audio material per participant), questionnaires (> 1,000 items), travel diaries (all trips occurring

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within three 1-week periods), and charging diaries (charging processes during two 1-week periods) were used to gain a comprehensive picture of the experience of, and behavior occurring within use of the electric mobility system (for further detail see [7]). The present contribution represents a targeted focus on one topic, within this comprehensive research project.

1.1 Participants

More than 700 people in the Berlin metropolitan area applied via a public online application form, to lease an electric vehicle for a 6-month period. From this sample of potential early adopters of electric vehicles, participants were selected first, according to several must-have criteria (e.g., possibility to install charging infrastructure) and second, ensuring diversification of users in terms of basic sociodemographic and mobility-related variables. If several users scored equally on these criteria selection was random.

The selected sample was, on average, 48.1 (SD = 8.9) years old and consisted of 33 male and 7 female users. Three quarters of users held a university degree. Three quarters of users had not yet experienced driving an electric vehicle. In 43% of households, at least one child under 18 years lived in the family. During the 6 months of electric vehicle usage there were only two dropouts.

1.2 Electric Mobility System

The electric vehicle used in the study had a range of 250 km under ideal conditions (168 km under normal conditions). The electric mobility system was further characterized by a regional focus on the urban area of Berlin, including a network of 50 public charging stations and personal home or office private charging stations available for users (full charge duration duration 4 h).

1.3 Measures

To assess the perceived fit of mobility needs and available mobility resources in terms of the range of an electric vehicle, two items were combined to generate one indicator score. The items were: “The electric vehicle has fulfilled my daily mobility needs” (“will fulfill” at T0), and “Planning car usage (planning of routes and charging duration) was a big challenge” (“will be” in

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T0). Users indicated agreement to these statements using a 6-point Likert scale ranging from 1 (*do not agree at all*) to 6 (*fully agree*).

The range comfort zone for each user was assessed using the range game, a method described in detail in [9]. In this game, users engaged in a standardized trip scenario, representing a critical range situation. The resulting score corresponds to remaining range in km (as indicated by a range display in the electric vehicle) that a user is no longer perfectly comfortable with when the distance to the next charging possibility is 60 km (i.e., users' range comfort zone).

Range, as a barrier for market acceptance was evaluated using scores of a question within the structured interview, at two time points: before receiving the car and after 3 months. Specifically, at both times, users were asked "In your opinion, what are the barriers for acceptance of electric vehicles?" All interviews were audiotaped and transcribed. For each user it was analyzed whether he or she mentioned range as a barrier for market acceptance (not necessarily a personal barrier).

The importance of range improvements for an increase in purchase intentions, was assessed using one item from a section in the questionnaire (same questions before receiving the car and after 3 months), where several key aspects of the electric mobility systems (e.g., price, charge duration, etc.) were listed. For each aspect, users rated the importance of improvements for enhancing individual purchase intentions. Users rated the importance on a 6-point Likert-scale ranging from *very unimportant* to *very important*.

Finally, one item was used to assess the extent to which users reported to have actively tested out the range of the electric vehicle (questionnaire after 3 months, T1).

3 RESULTS

The data of 35 users who had no missing data in the main study variables were entered in the analyses. All tests for significance were two-tailed at $\alpha = .05$. Estimates of effect size were computed using Cohen's d calculated from difference scores according to [11].

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There was a strong increase in the perceived fit between mobility needs and mobility resources (d = 0.80). As depicted in Figure 1, at the earliest time point, users were relatively positive about the electric vehicle fulfilling their mobility needs and the challenge that trip planning entailed, as evidenced in the interview before receiving the car (M = 4.17). This rating was even higher after 3 months (M = 4.99). This effect turned out to be significant (t(34) = 4.75, p < .001). A detailed analysis revealed that this effect was mostly caused by reduced skepticism about the difficulty of planning car usage. Yet, according to verbal protocols, need for planning was still perceived as a special feature of using the electric vehicle. Users that reported to have had actively tested out the range showed stronger experience effects in the mobility fit variable (r(34) = .42, p = .013).

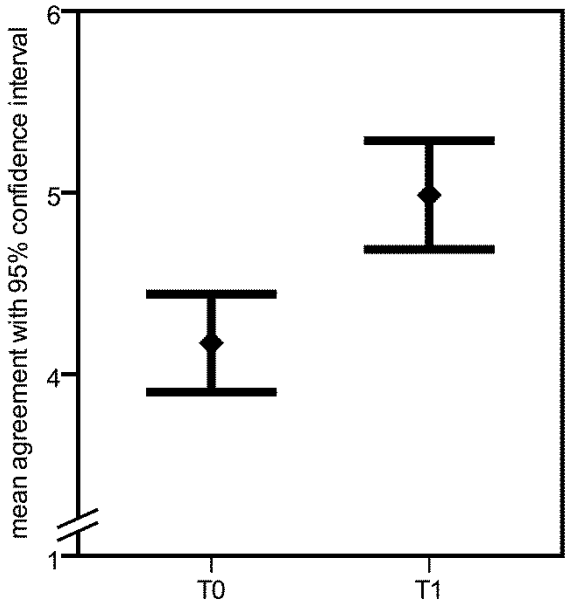

Fig. 1 Perceived fit of mobility needs and mobility resources before receiving the car (T0) and after 3 months (T1)

For the comfortable range variable from the range game a relatively small (d = 0.38) but reliable (t(34) = 2.25, p = .031) positive experience-related effect was found. As depicted in Figure 2, users were in general more comfortable with lower range levels after 3 months than before receiving the car. That is,

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their comfortable range limit for making a 60-km trip was on average 72.74 km after 3 months, while it was 77.06 km before receiving the car. Another indicator for comfortable range was assessed after 3 months (no data available for the time point before receiving the car): The maximum total trip distance that users were just not comfortable with anymore when using their electric vehicle. As these two scores correlated moderately ($r(34) = –.35$, $p = .049$), the experience effect measured with the range game may also be interpreted as a tendency that users with more experience were more comfortable taking longer trips. Again, users who reported to have had actively tested out the range in questionnaire after 3 months, showed moderately stronger experience effects in the comfortable range score from the range game ($r(34) = –.33$, $p = .059$).

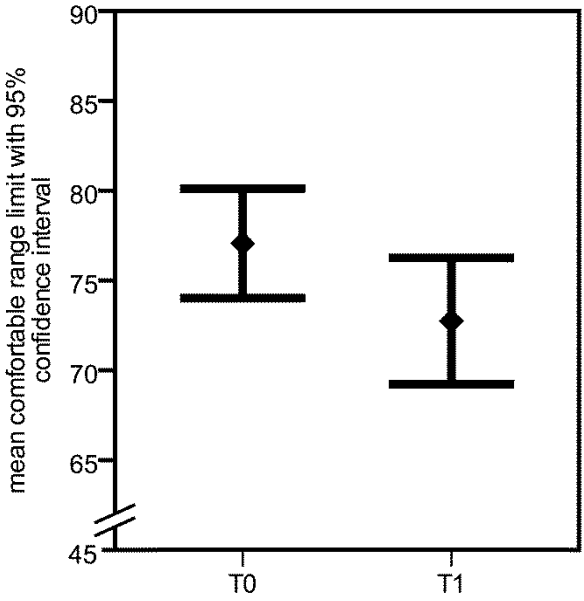

Fig. 2 Users' comfortable range limit (displayed available range) for making a 60-km trip as assessed by the range game before receiving the car (T0) and after 3 months (T1).

When electric vehicles users were asked about market acceptance barriers in electric vehicles, a weak increase ($d = 0.39$) in stating range as a barrier was found that reached the significance level ($t(34) = 2.32$, $p = .027$). These

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dichotomous data were analyzed using a t-test for easy comparability with the other analyses. Lunney [12] demonstrated that analysis of variance techniques can be validly used for dichotomous data under the given conditions. While 21 of 35 users mentioned range as a barrier for general market acceptance before receiving the car, 30 users mentioned it in the interview after 3 months.

Analyzing the importance of improvements in range of future electric vehicles for increasing users' purchase intentions resulted in a very weak relation between experience and users' importance-ratings of range improvements (d = –0.08) that was not significant ($t(34) = 0.49$, $p = .629$). Users judged improvements in range to be important both before receiving the car (M = 5.20) and after 3 months of experience (M = 5.11) although they mostly perceived a fit of mobility needs and mobility resources (see above) and also 31 of the 35 users agreed (dichotomization of 6-point scale item) that the range of the present electric vehicle was sufficient for everyday use (M = 4.97) after 3 months. This result is comparable to [13]. There the authors also found that users' range requirements did not change with experience with the electric vehicle and users wanted higher range throughout the study.

4 DISCUSSION

The present research examined the effect of experience on the perceived barrier that the range of an electric vehicle constituted. Electric vehicle experience was substantially related to an improvement in the perceived fit between mobility needs and mobility resources, and to an increase in comfortable (and thus, usable) range. In addition, there was some indication that actively exploring range resources led to an enhanced adaptation process. However, this effect did not seem to translate to a more positive general evaluation of range, that is, as less of a barrier for market acceptance. Interestingly, range was mentioned more often as a barrier for general market acceptance after 3 months, than before receiving the car. Finally, user preferences for a higher range remained constantly high over the two points of data collection. Hence, a gap remains between users' positive experience of available range resources (mobility fit) and their

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wishes for setups with higher available range. It would be fruitful to explore this gap and related variables in more depth in future research.

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