User interaction with remote access to range-related information in BEVs

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Abstract
Limited range can be a challenge for battery electric vehicle (BEV) users. Remote access to range-related information (e.g., via smartphone apps) could support users. The present study examines the experience and usage of range-related remote access functions in a BEV field study setting. Twenty-nine customers leased a BEV for three months and had access to a remote-access app. On average, users perceived the range-related remote access functions as moderately supportive and usage frequency was typically between occasionally and often. Higher usage frequency was associated with more irregular/unpredictable daily mobility patterns, a higher share of away-from-home recharging, and typically less available charging time, yet affinity to technology was not. The study shows the usefulness of range-related remote access functions and identifies the user groups that might particularly benefit from these functions and therefore, should be targeted in research and development aimed at advancing remote-access functions.

Keywords:
electric vehicles, remote access functions, user-range interaction

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1 Introduction

Battery electric vehicles (BEVs) are a promising form of sustainable mobility because of their potential to reduce CO₂ emissions and air pollution (Holdway, Williams, Inderwildi, & King, 2010), as well as their potential to mitigate risks associated with peak oil (Hirsch, Bezdek, & Wendling, 2005). However, limited range is a challenge for the widespread adoption of BEVs. Although substantial improvements in electric vehicle battery performance are expected within the coming years, smaller but suitable battery sizes will always constitute a more sustainable battery layout because battery size is strongly related to the ecological footprint of an electric vehicle (Hawkins, Gausen, & Strømman, 2012; McManus, 2012). The cost-effectiveness of batteries also plays a major role in buying decisions. Even with declining battery costs, it is likely that a large share of customers will not automatically opt for the largest possible battery, but will instead compromise between their daily driving needs and a suitable battery size. As a consequence, the following question in research and development will remain relevant: How can the maximum usable range be provided for the customer given a certain nominal battery capacity?

Research has shown that it is challenging for users to interact with limited battery resources in an optimal way. For example, it has been shown that users tend to avoid situations that would lead to range stress (i.e., range anxiety) by reserving substantial range safety buffers (i.e., around 20% of real available range; Franke, Neumann, Bühler, Cocron, & Krems, 2012; Franke & Krems, 2013). Their limited range comfort zone (i.e., comfortable range; Franke & Krems, 2013) results in a usage pattern in which a certain share of the battery capacity is lost as a psychological safety buffer.

Intelligent transport systems (ITSs) could support users in their daily interaction with BEV range by enhancing the range-related user experience and extending the usable range. One function that is thought to be particularly valuable for BEV users in this regard is the remote access to range-related information (e.g., current remaining range, the remaining charging time; Nilsson & Habibovic, 2013), which can be provided via a smartphone application (app) that can sync with the BEV. Yet, little is known about how users interact with and experience such a system in everyday use. Part of the reason for this lack of research is that BEVs have not yet entered the mass market and smartphone apps that provide remote access to range-related information are not available with all BEV models that are currently on the market. Field tests that focus explicitly on the evaluation of certain ITS functions can have problems with external validity. For example, it is difficult to observe “natural” (i.e., everyday) usage behavior because it can be challenging to include real customers in research studies, the focus of the research is clear to the participants, and participants may even be asked (i.e., strongly encouraged) to use the ITS function. In sum, it is difficult to design appropriate test conditions for studying everyday interaction with range-related remote access functions in BEVs. Substantial care has been taken to consider these challenges when planning the present field trial.

The objective of the present research is to better understand how BEV users experience and interact with remote access to range-related information in everyday BEV use, as well as to determine which factors are associated with frequent usage of such remote access functions. To this end, data from a long-term field study was analyzed in which 29 private customers leased a BEV for a 3-month period and had access to a smartphone app that could remotely display range-related information. The study methodology was designed to achieve high ecological validity in terms of how the participants were recruited as well as how the remote access functions were incorporated into the study. Notably, the sample consisted of people who usually had to travel relatively long daily distances with the BEV (e.g., on long daily
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commutes), typically requiring daily charging. Hence, it can be assumed that they had to actively interact with range on an everyday basis, indicating that they might benefit from range-related ITS functions.

Specifically, we address the following research questions within this contribution:

(Q1) How much do BEV users feel supported by range-related remote access functions?

(Q2) How much do BEV users make use of range-related remote access functions?

(Q3) Which factors are related to a more intensive usage of range-related remote access functions? In other words: Which types of users will use these functions in particular?

Regarding Q3, the following hypotheses are tested:

(H1) Based on previous research (Franke et al., 2012), it can be assumed that BEV users tend to develop certain heuristics and routines to cope with the range. For users with a highly regular/predictable daily mobility pattern, this may be even more likely, as they often encounter very similar range situations. Consequently, their range-related trip decisions may seldom need additional information (e.g., via remote access functions). Users with more irregular/unpredictable daily mobility patterns might need to make more context-dependent (i.e., complex) range-related trip decisions and may therefore need additional information on the current energy status of the BEV more frequently. Consequently, we hypothesize that more irregular/unpredictable daily mobility patterns will be related to a more intensive usage of range-related remote access functions.

(H2) Remote access to range-related information is typically relevant for planning of, or deciding on, trips when the car is currently being charged. For users who primarily charge at home overnight, such situations should rarely occur because typically either the BEV is fully charged or the remaining range is at the same (presumably high) level as it was at the end of the last trip (i.e., before initiating a charge). Consequently, we hypothesize that a higher share of away-from-home recharging events will be related to a more intensive usage of range-related remote access functions.

(H3) In addition to charging location, it is probable that the likelihood of utilizing remote-access to range-related information is associated with the amount of energy that usually must be charged within a given time span. Users who typically (have to) charge more energy (i.e., start with lower charge levels) and have less time for the charging process before the next trip starts are expected to use remote-access more frequently (i.e., on a more regular basis). Consequently, we hypothesize that users who typically have less time available for charging a certain amount of energy (i.e., between two trips) use the range-related remote access functions more frequently.

(H4) A common assumption regarding the usage of innovative technological systems is that a higher affinity to technology is related to a more intensive usage of such systems (Weiss, Loock, Staake, Mattern, & Fleisch, 2010). Also, regarding the usage of the range-related remote access functions, it seems plausible that those users who (1) have a higher affinity and motivation for exploring the new technological elements of the BEV mobility system or (2) have a higher motivation (i.e., affinity) for exploring available car functions in general, will use those remote functions more often. Consequently, we hypothesize that these two specific facets of affinity to technology are positively related to more frequent use of range-related remote access functions.
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2 Method

2.1 Field trial setup

The present research was part of a large-scale BEV field trial in the region surrounding Leipzig, Germany. This field trial was set up by a consortium consisting of the BMW Group, the Stadtwerke Leipzig (SWL, Leipzig municipal utilities), and Technische Universität Chemnitz and was funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The field trial was designed as a longitudinal study that involved three main points of data collection: Before users received their BEV (T0) including a short additional data collection event after users had gained their first experience with the BEV after approximately one week of BEV use (T0+1), after six weeks of BEV use (T1) and at the end of the trial after twelve weeks (T2). At each point of data collection, users completed a 2- to 3-hour face-to-face interview including questionnaires. Additionally, participants filled out travel as well as range-and-recharging diaries and data loggers automatically recorded several parameters. The field trial used a person-based main user data collection approach meaning that only data from the main user of the BEV was collected and analyzed. For the present study, data analysis was conducted using data from T0, T1, and T2 questionnaires, as well as data from the range-and-recharging diary. Further details on the methodology have been reported elsewhere (Franke, Günther, Trantow, Krems, Vilimek, & Keinath, 2014).

2.2 BEV used during the field trial

The BEV used in this study was the BMW ActiveE, an electric conversion vehicle based on a BMW 1 Series Coupé with a maximum available driving range between 130 and 160 km in real terms, depending on driving style (Ramsbrock, Vilimek & Weber, 2013). It took 4-5 hours to fully charge the battery using a 32 A charging station and 8-10 hours using a normal socket. Customers could access, amongst other data, information on battery charge level, range, energy consumption, and the charging process: The estimated remaining and full charge range were displayed based on energy consumption over the last 30 km (as stated in the user manual), the state-of-charge was displayed (0-100%), the current and average energy consumption were displayed (including an energy consumption history display with averages given at 1-minute intervals for the current trip), and during charging processes, the estimated time until the vehicle was fully charged was displayed. For this field trial, the standard series version of the BMW ActiveE was slightly modified. The series version comes with an ECO PRO mode that can be selected to automatically adjust the drive configuration and comfort functions to achieve a higher range. For this field trial, the ECO PRO mode was deactivated, partly to maintain greater control over the available range for the users, but also to allow for testing of different configurations of the regenerative braking system.

2.3 Energy monitoring smartphone app

Participants in the present study had access to advanced online vehicle functions including the “My BMW remote” smartphone app that could be used to remotely control certain functions (e.g., starting/stopping a charging process, preconditioning of the battery and passenger compartment), and monitor certain parameters (e.g., remaining range, remaining time until fully charged, charging status). For the present study, we were interested in participants’ subjective experience and usage of the energy status information (see Figure 1), specifically the current range, charge level, and remaining charging time displays. If participants wanted to use the app they had to install the app on their own smartphone or tablet (Android or iOS). Participants were given information on the availability of the remote app and received support for installing and initializing the app (i.e., performing the authentication process), if needed.
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Yet, participants were not asked to install or use the remote app, as the specific aim of the study was to examine participants’ “natural” usage and subjective experience of the functions in everyday BEV use.

Figure 1 – The remote app energy status display during a charging process (original display was in German and metric units).

2.4 Participants

In order to recruit interested customers from the general public, information on the project was distributed via radio, local television, newspaper, online media, partner websites, public events, and informational stickers on the BEVs. People could apply by accessing a public website via one of several short links (e.g., bmw.de/testfahrer) and completing an online questionnaire on this website. Nearly 650 people applied before the recruitment of the present sample was completed.

Applicants were included in the final selection if they: (1) were willing to pay the monthly leasing rate of 450 € and the costs for electricity, (2) had at least one charging opportunity or the possibility of installing a charging station at home and/or work (dependent on the prospective daily distance driven with the BEV), (3) were willing to take part in data collection, (4) had a mobility profile that would be expected to result in a frequent active interaction with range (i.e., at least 90 km daily driving distance with the BEV), and (5) lived or worked in the area around Leipzig (max. 120 km away).

After screening for the inclusion criteria (see above), participants were primarily selected and prioritized based on the frequency with which they were expected to interact with range (i.e.,
combined analysis of daily driving distances and available charging opportunities. As restrictions for inclusion in the sample were similar to those for leasing a BEV (e.g., users paid an EV-adequate monthly leasing-rate, needed charging opportunity), we expect the sample to represent a population of early adopters (i.e., early customers) of BEVs in Germany.

The 29 users who completed at least T1 had an average age of 41.1 years (SD = 8.1), 5 were female, 14 had a university degree, and 24 had an Android/iOS smartphone or tablet when applying for the trial (during the trial one additional user bought a smartphone to be able to use the remote app). Moreover, users estimated at T0 that their average daily driving distance by car was approximately $M = 120$ km (SD = 40 km).

2.5 Scales and measures

2.5.1 Subjective experience of and interaction with remote access functions

Three items in the T1 questionnaire assessed subjective experience of the remote access functions in terms of general (item 1) and range-related (item 2 and 3) perceived support on a 6-point Likert scale from (1) “completely disagree” to (6) “completely agree” (items are displayed in Table 1). Furthermore, two items assessed the frequency of using range-related remote access functions on a 6-point frequency scale from (1) “never” to (6) “always” (items are displayed in Table 2). Only participants who had installed the smartphone app answered all items ($N = 23$, see section 3). The two items assessing range-related perceived support yielded a Cronbach’s alpha = .85. Thus, for the analysis in section 3.3, a mean score (perceived range-related support) was computed for these two items. The two usage frequency items yielded a Cronbach’s alpha = .78. Therefore, for further analyses a mean score (usage frequency) was computed for these two items.

2.5.2 Regularity/predictability of daily mobility patterns

Eleven items were administered at T0 to assess regularity/predictability of users’ daily mobility patterns. Items were, for example, “I know which trips I will take the next day” or “Regarding trip distances, almost every workday is actually the same for me”. Users rated these items on a 6-point Likert scale from (1) “completely disagree” to (6) “completely agree”. Item values were reverse coded if needed and a mean score was computed with high values indicating high regularity/predictability. Cronbach’s alpha of the scale was .93.

2.5.3 Charging location

In the T2 questionnaire, six types of charging opportunities were displayed (private charging station at home, normal socket at home, charging station at work, normal socket at work, public charging station, other) and participants estimated which percentage of charging events took place at each location over the whole trial. For all but one user, values summed up to 100% (90% for this single user, therefore values were multiplied by 1.111 to obtain comparable values; results of the analyses did not change remarkably with/without the transformation of the values for this user). From this information, the proportion of away-from-home recharging events was computed.

2.5.4 Range and recharging diary

The range-and-recharging diary data was analyzed to test H3. Before T2, users were asked to record their daily trip and recharging behavior over a period of at least 10 days within a diary (similar to a driver’s logbook). For each trip, participants logged the following variables at the beginning and at the end of the trip: time, odometer reading, information on range and charge
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level, the availability and the use of a charging opportunity at the end of the trip, as well as the user (main user of the BEV vs. secondary user). For the present analysis, we were only interested in the main users’ trips that were followed by a charging event. For each charging event, we computed the remaining time in minutes until the next trip started and divided this by the amount of energy that needed to be charged (i.e., 100 – the current state of charge). The resulting variable was labeled available charging time. We then computed the mean value of this variable for each user who had at least six charging events with no missing data and who also had installed the remote app (N = 21).

2.5.5 Affinity and motivation for exploring new BEV technology

Four items were administered at T0 to assess the affinity and motivation for exploring the new BEV technology. Items were, for example, “I am looking forward to acquainting myself with the BEV in more detail” or “The new technology of the BEV intrigues me”. Users rated those items on a 6-point Likert scale from (1) “completely disagree” to (6) “completely agree”. A mean score was computed. Cronbach’s alpha of the scale was .84.

2.5.6 Affinity for exploring and using new car functions

Four items were administered at T0 to assess the general affinity for exploring and using car functions. Items were, for example, “When I use a new car I try out all functions and settings.” or “I enjoy navigating through menus (e.g., of navigation devices or mobile phones)”. The second example item was the only one of the 4 items that also referenced mobile phones. Yet, this item was kept in the scale as the corrected item-total correlation was still acceptable for this item (r = .4) and it covered a facet that is relevant to the present research. Users rated the items on a 6-point Likert scale from (1) “completely disagree” to (6) “completely agree”. A mean score was computed. Cronbach’s alpha for the scale was .78.

3 Results

At T1, 23 of the 29 users had installed the smartphone app which was required in order to access the remote access functions on their smartphone. Of the remaining 6 users, 4 stated as a reason that they had no smartphone/tablet, 1 user did not want to pay for mobile internet, and 1 user simply stated that he did not need the remote access functions. In the following analyses, only the data from the 23 users who had installed the smartphone app is analyzed. As the sample size in the present study was small, we primarily base our interpretation of the results on the effect size and not on the statistical significance of the results.

3.1 Subjective experience of remote access functions

Regarding Q1 “How much do BEV users feel supported by range-related remote access functions?”, data indicated (depicted in Table 1) that nearly all users generally perceived remote access functions as valuable (first item). For the %-agreement value in Table 1, we dichotomized the 6-point Likert scale and computed the percentage of users who endorsed scale values from 4 “slightly agree” to 6 “completely agree”. As can be seen from the minimum rating, there were no users who evaluated remote access functions as being completely useless. As may be expected from this pattern of results, testing the users’ rating of this item against a value of 3.5 (the value indicating that an participant endorsed indifference regarding this statement) yielded a large and highly significant effect (t(22) = 6.34, p < .001, d = 1.32, two-tailed test). Effect size for this and all following tests were calculated with GPower 3.1.7 (Faul, Erdfelder, Lang, & Buchner, 2007). All other calculations were executed with SPSS 20.
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Regarding the two items that focused more specifically on perceived support in managing range, a majority of the users still tended to feel supported. Yet, when inspecting the mean score of these two items, users only perceived the available functions as moderately supportive, which consequently yielded a small and insignificant effect when testing the users’ ratings of these items against a value of 3.5 ($p > .3$, $d < 0.2$, two-tailed test). Notably, there was high inter-individual variance in users’ ratings (see also minimum and maximum values), indicating that the range-related remote access functions provided support in managing range for some users, but not for others. It is important to note that although a high rating on these items can be interpreted as meaning that the app function is experienced as supportive, a low rating can indicate that either users do not feel supported by this specific function (i.e., suboptimal function design) or that users do not require support (e.g., users already perceive the interaction with range as easy or perceive it as easy after adaptation to limited range).

Table 1 – Perceived support by range-related remote access functions. Rating on a scale from 1 to 6 ($N = 23$).

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>% agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The remote access to vehicle functions via the app provides valuable support for using the BEV.</td>
<td>4.61</td>
<td>0.84</td>
<td>3</td>
<td>6</td>
<td>96%</td>
</tr>
<tr>
<td>2. The app makes it easier to deal with the range of the BEV (e.g., retrieving and planning the range).</td>
<td>3.74</td>
<td>1.32</td>
<td>1</td>
<td>6</td>
<td>61%</td>
</tr>
<tr>
<td>3. The app gives me confidence when dealing with the range.</td>
<td>3.39</td>
<td>1.12</td>
<td>1</td>
<td>5</td>
<td>57%</td>
</tr>
</tbody>
</table>

3.2 Usage of remote access functions

Regarding Q2 “How much do BEV users make use of range-related remote access functions?”, data indicated (depicted in Table 2) that users on average used the remote access to range/battery charge level information often (= scale value 4) and the remote access to the remaining charging time occasionally (= scale value 3). Yet, comparable to the pattern observed in Q1, there was also substantial inter-individual variance in users’ frequency ratings. There were both several users who used the functions “never” or “almost never” (= scale values 1-2) and several users who used them “always” or “almost always” (= scale values 5-6).

Table 2 – Frequency of usage of range-related remote access functions ($N = 23$).

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>%1-2</th>
<th>%3-4</th>
<th>%5-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I use the function for retrieving the current range/charge level.</td>
<td>3.83</td>
<td>1.19</td>
<td>1</td>
<td>6</td>
<td>13%</td>
<td>65%</td>
<td>22%</td>
</tr>
<tr>
<td>2. I use the function for retrieving the remaining charging time.</td>
<td>3.00</td>
<td>1.35</td>
<td>1</td>
<td>6</td>
<td>35%</td>
<td>57%</td>
<td>9%</td>
</tr>
</tbody>
</table>
3.3 Relationship between perceived support and usage frequency

In order to better understand the inter-individual differences in responses to items assessing Q1 and Q2, we conducted a correlation analysis between the perceived range-related support and usage frequency scores after testing for univariate outliers according to the procedure and thresholds proposed by Grubbs (1969) (result: no univariate outliers present), testing for univariate normal distribution with the Kolmogorov–Smirnov test (result: normal distribution could be assumed for the two variables), and inspecting a scatter plot of the two variables. The scatter plot revealed that there was only one case that markedly changed the magnitude of the effect (none of the other cases had a substantial individual influence on the effect). Therefore, we computed the correlation with \( r = .32, p = .143 \), two-tailed test and without \( r = .73, p < .001 \), two-tailed test) this influential case. As can be seen from these results, there was a moderate to strong positive relationship between perceived range-related support and usage frequency. Indeed, it seems intuitive that people refrain from using the app if the app does not support their user-range interaction or if they do not need the support. Notably, this pattern might also indicate that interaction with (i.e., frequent usage of) the remote access functions may be driven more by the need to use such functions (i.e., pragmatic usage motives) rather than, for example, by factors like affinity for technology (i.e., hedonic usage motives; Hassenzahl, 2007; Hassenzahl, Schöbel, & Trautmann, 2008).

3.4 Regularity/predictability of daily mobility patterns and usage frequency

To test hypothesis H1, we tested for univariate outliers (result: no outliers observed), and univariate normal distribution (result: no violation of normality assumption). In addition, we examined a scatter plot of the two variables (result: no individual influential cases or other anomalies) using the same procedures as outlined in section 3.3.

Consistent with hypothesis H1, there was a moderate negative relationship between perceived regularity/predictability of daily mobility patterns and usage intensity of the range-related remote access functions \( r = -.41, p = .026 \), one-tailed test because of directional hypothesis). Thus, users who had highly irregular/unpredictable daily mobility patterns tended to use the range-related remote access functions more frequently.

3.5 Proportion of away-from-home charging events and usage frequency

To test hypothesis H2, we tested for univariate outliers and univariate normal distribution of the involved variables. The distribution of the charging location variable violated assumptions of normality according to the Kolmogorov–Smirnov test even though this variable was broadly distributed (i.e., restricted variance did not seem to cause violation of normality). Consequently, we additionally analyzed our data with a \( t \)-test that is more robust to violations of normality.

Consistent with hypothesis H2, there was a marginally significant positive relationship (moderate effect size) between the proportion of away-from-home charging events and the usage frequency of range-related remote access functions \( r = .34, p = .054 \), one-tailed test because of directional hypothesis). For the \( t \)-test analysis, we dichotomized the usage frequency scale (group 1: \( \leq 3 \) meaning never, almost never, and occasionally; versus group 2: \( \geq 4 \) meaning often, almost always, and always). Two users had a value of 3.5 on the usage frequency score and were therefore not categorized into either group. The \( t \)-test revealed that the “infrequent users” of the range-related remote access functions \( n = 11 \) did indeed charge away from home less frequently \( M = 26.97\% \) of all charging events, \( SD = 23.46 \) than the “frequent users” \( M = 58.70\% \) of all charging events away from home, \( SD = 36.98 \). The observed effect was large and significant \( t(19) = 2.37, p = .014, d = 1.02 \), one-tailed test).
3.6 Available charging time and usage frequency

To test hypothesis H3, we tested for univariate outliers, univariate normal distribution and inspected a scatter plot of the two variables (result: no problems identified). Consistent with hypothesis H3, there was a significant negative relationship (moderate effect size) between the average available charging time (i.e., time to charge a certain percentage of the battery) and the usage frequency of the range-related remote access functions ($r = -0.42$, $p = 0.030$, one-tailed test because of directional hypothesis). Thus, users who typically had less available charging time used the remote access functions more frequently.

3.7 Affinity for technology and usage frequency

To test hypothesis H4, we tested for univariate outliers, univariate normal distribution and inspected a scatter plot of the variables. The distribution of the two affinity for technology variables violated assumptions of normality according to the Kolmogorov-Smirnov test. This finding might be partially attributable to substantially restricted variance in our sample (i.e., scores were only in the upper half of possible values). Nevertheless, a visual examination of histograms revealed that the variables appeared to possess substantial variance. Finally, we decided to compute both, t-tests (i.e., compare infrequent and frequent users similar to section 3.5) and correlations.

Regarding the first facet, affinity and motivation for exploring BEV technology, only an insignificant positive relationship (small effect size) was revealed ($r = 0.13$, $p = 0.276$, one-tailed test because of directional hypothesis). The t-test also revealed a very small and insignificant effect ($t(19) = 0.60$, $p = 0.476$, $d = 0.02$, one-tailed test). Regarding the second facet, general affinity for exploring car functions, a significant negative relationship (moderate effect size) was revealed ($r = -0.46$, $p = 0.014$, one-tailed test). This finding is contrary to our hypothesis and the same effect was also found using the t-test ($t(19) = 2.37$, $p = 0.014$, $d = 1.04$, one-tailed test). Therefore, these results do not support H4.

4 Discussion

The objective of the present research was to better understand BEV users’ subjective experience of, and interaction with, remote access to range-related information, and to determine which factors are associated with frequency of remote access function use. In summary, (Q1) users in general perceived range-related remote access functions as moderately supportive (substantial inter-individual variance was observed), with increased perceived support being related to more frequent utilization of these functions. Furthermore, (Q2) users typically used range-related remote access functions from occasionally to often. Finally (substantial inter-individual variance was observed). Finally, (Q3) it was found that more frequent use of remote access functions was associated with irregular/unpredictable daily mobility patterns (H1 confirmed), a higher proportion of away-from-home recharging events (H2 confirmed), and having less available charging time (H3 confirmed); but not with affinity for technology (H4 disconfirmed).

The present contribution represents a first step towards advancing our understanding of users’ subjective experience and utilization of remote access functions in realistic everyday conditions. The remote access functions were examined as one possible element of an intelligent transport system designed to support users in their daily interaction with electric vehicle range. The present study provides initial evidence indicating that remote access functions might be useful in helping users cope with limited range, as users felt supported in their daily interaction with limited range. Furthermore, the results indicate that it is unlikely that all users will utilize remote access functions. In general, the results indicate that usage is
not driven by a higher affinity for technology (i.e., hedonic usage motives; Hassenzahl, 2007; Hassenzahl, Schöbel, & Trautmann, 2008), but rather by a need to use certain functions (i.e., pragmatic usage motives). Yet, it is important to note that variance of the affinity to technology indicators was restricted in this sample (see section 3.7.). Therefore, it is still possible that there is a positive relationship between affinity for technology and usage frequency in a population that also includes people with very low affinity for technology (e.g., that there is a certain minimum affinity for technology that is necessary for people to use remote access functions regularly). However, for the population of early adopters (i.e., early customers; see Rogers, 2003) who tend to have an affinity for exploring and using technology, the usage frequency of remote access functions might not be driven by affinity to technology, but rather by necessity. The results of the present study suggest that frequency of function utilization is associated with more complex/irregular mobility behavior that incorporates many “in-between” charging processes (i.e., with limited time to charge) away from home. This is likely because individuals who fit this profile have a greater need to remotely monitor range and recharging processes more frequently. Consequently, these groups of users should be targeted when further developing range-related remote access functions. For people who can charge overnight at home and who have regular daily mobility patterns, range appears to be manageable without remote access functions even if they have to drive substantial daily distances with the BEV on a daily basis as in the present study.

Yet, it is important to note that the present study only incorporated the most basic range-related functions of remote access apps. Thus, the benefits of range-related apps for BEV drivers may substantially increase if the driver is able to access more information and exercise more control over range-related parameters. For instance, apps can provide information on available range in different driving modes to support more detailed trip planning. Most electric vehicles offer driving modes with reduced driving performance or comfort functions in order to gain additional range. For instance, the BMW i3 allows the customer to choose between standard driving mode, an ECO PRO mode with only marginal reductions in comfort and performance in exchange for increased range, and an ECO PRO + mode that reduces nonessential power consumption to a minimum if an unexpected range need arises. If smartphone-based remote functions mirror these functional dependencies, it can be expected that these systems will play an increased role in trip planning compared to the status quo of this research.

Finally, the present study has some limitations that should be considered when interpreting the results. Given the field study research design, inferences about causal relationships cannot be easily drawn. Moreover, the present study had a very small sample size. This calls for replication studies with larger sample sizes to test for the robustness of the present results.

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References


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