Supplementary Information for: A behavioral intervention to reduce range anxiety and increase electric vehicle uptake

Masked for double-blind peer review

Note 1: Validity of the actual compatibility measure

Our approximation of the actual compatibility of BEV battery ranges is based on participants' self-reported past driving. Despite our careful instructions, we cannot exclude that these self-reports did not suffer from memory distortion [1] or under-reporting [2]. However, the following observations support the quality, validity, and usefulness of the measure.

On an aggregate level, the compatibility computed in the present research largely mirrors the compatibility computed by studies applying rigorous GPS-tracking to capture individuals' driving behavior [3–8]. Melliger et al. (2018) for example estimate that "85 - 90 % of all national trips [in Finland and Switzerland] could have already been covered with BEVs prevalent in 2016". Similarly, Rafique and Town (2019) estimate based on data from New South Wales (AUS) that a BEV with a moderate battery range of 75 miles/120 km (i.e., 19.2 kWh usable battery capacity) would retain more than 70 % of its battery charge for 92 % of all vehicle trips.

Additionally, U.S. *National Household Travel Survey* research comparing self-reported recall and a travel diary methodology suggests that self-reports mainly lead to the under-reporting of incidental trips: unplanned, spontaneous car trips that tend to be of shorter distance [9, 10]. Thus, for the computation of the actual compatibility in the present research, the potential under-reporting of shorter, incidental trips might have resulted in an underestimation of the true compatibility of some individuals and might therefore be considered a conservative measure of compatibility. To prompt participants to recall as many car trips as possible of both short and long distances, we carefully designed the instructions for the self-report (see detailed stimuli at the end of the SI) and regrouped travel distances into distance bins most prevalent in Germany [11] and the U.S. [12] to facilitate responses.

Finally, most research based on GPS-tracking has computed compatibility as the *percentage of travel days* covered by a BEV with a given battery range [3, 4, 6, 7], and not as the *percentage of annual car trips* as in the present work. Computing compatibility based on single car trips implicitly contains the assumption that BEVs may be charged at the origin and the destination of a car trip. We acknowledge that this might currently still be a challenge, due to lack of charging infrastructure and long charging times [13], but may soon reflect reality. Moreover, two additional reasons motivated us to compute compatibility based on self-reports of single car trips instead of daily distance travelled. First, we aimed to use a procedure that could be easily reproduced and tested by other scholars or practitioners, thus requiring little input from consumers. Secondly, reconstructing driving distances per day would have been an additional burden on respondents' recall and would have certainly reduced the quality of our data [10]. Finally, the immediacy of providing potential consumers with estimations of compatibility may be a crucial component of the intervention presented here. When presented with the compatibility information in Study 2a and 2b, car owners received immediate feedback about the compatibility of BEVs with their driving needs, which would not have been possible with a GPS-based computation. Judging from our results, respondents considered the compatibility information trustworthy and useful and integrated it in their answers of the willingness to pay task. In additional support of this reasoning, respondents reported relatively high trust in the battery range information across conditions (M = 4.60, SD = 1.34, on a scale from 1 to 7). If respondents had been suspicious about our approximation of compatibility based on their self-reports, one would have expected significantly lower explicit trust ratings in the compatibility condition.

Note 2: Buying intentions and range requirements predicted by perceived and actual compatibility separately

We analyzed the effect of the compatibility bias, computed as the difference between participants' perceived and actual compatibility, on participants' purchase intentions and range requirements. While this approach is in line with the concept of cognitive biases [14] and recent research applying a similar approach in the domain of energy and food consumption [15, 16], an alternative way of analyzing our data is to introduce perceived and actual compatibility as separate predictors of buying intentions and range requirements. In line with previous research [17], we expected that higher perceived compatibility would predict higher purchase intentions, while higher actual compatibility should not, because consumers seem to be unaware of it. Similarly, we predicted that higher perceived compatibility leads to lower range requirements, while higher actual compatibility should not. The results were in line with these hypotheses (see Supplementary Table 3).

Note 3: ANOVA results of range anxiety by condition

In Study 2b, before contrasting conditions, we conducted an ANOVA to determine the overall effects of battery range, experimental condition, and their interaction on range anxiety. The ANOVA yielded a main effect of battery range, $F(1, 999) = 1579.85, p < .001$, a main effect of experimental condition, $F(2, 999) = 9.81, p < .001$, and an interaction between battery range and experimental condition, $F(2, 999) = 9.13, p < .001$. In the next step, we compared the regression coefficients of the slope relating battery range with range anxiety between conditions, as reported in the main text.

Note 4: Computation of TCO and applied assumptions

We followed past research [18] in our computation of consumers' total cost of ownership (TCO) of their current car in Stud 2a and 2b. TCO was approximated as the sum of participants' annual fuel costs, depreciation costs, repair costs, tax and insurance.

We computed annual fuel costs as the product of annual mileage and the current fuel price (2.73$ per gallon and 1.25€ per liter at the time of data collection). Annual mileage was approximated on the basis of participants' self-reported driving behavior. To do this, we multiplied the self-reported frequencies by the mid-point of the respective distance categories (see Methods in the main text). For the >400 km and the >240 miles category we used the average between the geographical width and height of Germany and the U.S., respectively (i.e., 758 km and 2200 miles). We removed n = 26 outliers from the 279 participants in the German sample and n = 80 from the 999 participants in the U.S. sample, situated more than 1.5 times the interquartile range above the upper quartile. After the exclusion, the average annual mileages of 11095.5 km (*SD* = 8442.9) and 9791.4 miles (*SD* = 8545.1) slightly underestimated the population averages in Germany (13,600 km; [19]) and the U.S. (11,113 miles; [20]).

Depreciation cost were computed on the basis of the original purchase price of a car and its age. Following [18], annual depreciation was determined to be 25% of the original purchase price for cars aged less than 2 years, 15% for cars aged 2 years, 10% for cars aged 3 years, 5% for cars aged more than 3 until 10 years, 1% for cars aged more than 10 and less than 16 years, and 0% for cars aged 16 years and more. Monthly depreciation costs amounted to 180.6€ (*SD* = 268.6) in the German sample and 154.7$ (*SD* = 188.7) in the U.S. sample.

Because our data did not contain any information about the repair and tax and insure costs of participants' cars, we relied on external sources for their approximation. Based on data from the German Automobile Club, we estimated monthly repair costs of 60€ and tax and insurance costs of 100€ for cars with an original purchase price of < 40,000€ and repair costs of 120€ and tax and insurance costs of 200€ for cars with an original purchase price of > 40,000€ [21]. This distinction between lower and higher priced cars was made because repair and tax and insurance costs depend more strongly on the vehicle class in Germany (small-medium vs. luxury) than in the U.S.. Based on data from the American Automobile Association, we estimated monthly repair costs at 99$ and monthly insurance costs at 133$ [22].

Note 5: ANOVA results of condition-TCO interaction on WTP

In Study 2b, before contrasting conditions we conducted an ANOVA to determine the overall effect of the interaction of experimental condition and TCO. The ANOVA yielded a main effect of condition, $F(2, 848) = 18.95, p < .001$, no main effect of TCO, $F(1, 848) = 2.58, p = .11$, and the interaction between condition and TCO, $F(2, 848) = 12.18, p < .001$.

In the next step, we analyzed the regression coefficients of the slope relating TCO with willingness to pay between conditions, as reported in the main text. Including age, gender, and car trip frequency as covariates did not change the statistical significance of the interaction parameters of compatibility intervention and TCO, neither in the German ($b = 1298.7, t(236.0) = 2.62, p = .01$) nor the U.S. sample ($b = 2112.9, t(847.02) = 4.5, p < .001$).

Note 6: Regression results with separate TCO components

To learn more about the underlying factors of the interaction of experimental condition and TCO in predicting willingness to pay, we adapted the linear mixed-effects model to include fuel costs (i.e., the product of annual mileage, fuel consumption and fuel price) and depreciation costs (i.e., a combination of car age and price - see Supplementary Note 4 for details) instead of overall TCO in Study 2a and 2b.

In Study 2a regression results yielded a steeper slope relating depreciation costs and willingness to pay in the compatibility condition than in the control condition, $t(236.0) = -1.94, p = .053$, as well as a steeper slope relating fuel costs and willingness to pay, $t(236.0) = -2.19, p = .03$.

In Study 2b, before contrasting conditions we conducted an ANOVA to determine the overall effect of the interaction of experimental condition and fuel costs and depreciation costs. The ANOVA yielded a significant main effect of condition ($F(2, 848.01) = 19.03, p < .001$), a significant interaction between depreciation costs and condition, ($F(2, 848.01) = 10.97, p < .001$), and no interaction between fuel costs and condition, ($F(2, 848.01) = 2.26, p = .11$). Inspection of the individual interaction parameters indicated that the slope relating depreciation costs and willingness to pay was steeper in the compatibility condition than in both the control condition, $t(848.0) = -4.51, p < .001$, and the infrastructure condition, $t(848.0) = -3.73, p < .001$. The slope relating fuel costs and willingness to pay was steeper in the compatibility condition than in the infrastructure condition, $t(848.0) = -2.13, p = .034$, but not compared to the control condition, $t(848.0) = -0.97, p = .335$.

Taken together, these results suggest that high current fuel and depreciation costs may account for the increased effectiveness of the compatibility intervention for car owners with higher TCO. It seems that consumers are somewhat aware if a BEV would be a financially beneficial investment for them or not. When the benefits are given, car owners seem to respond positively to compatibility information with increased WTP for BEV.

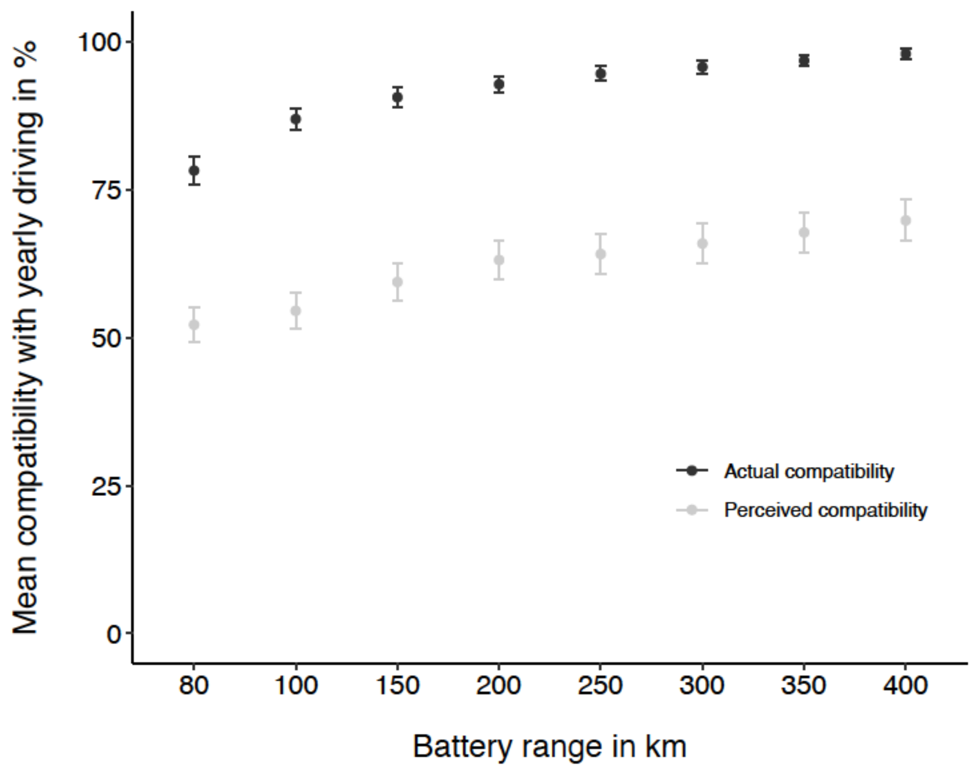

FIGURE 1: Perceived and actual compatibility of BEV with individual mobility needs in a representative car owner sample from Germany (Study 1a, N = 438). The size of the underestimation was stable across different battery ranges. Error bars indicate 95% confidence intervals.

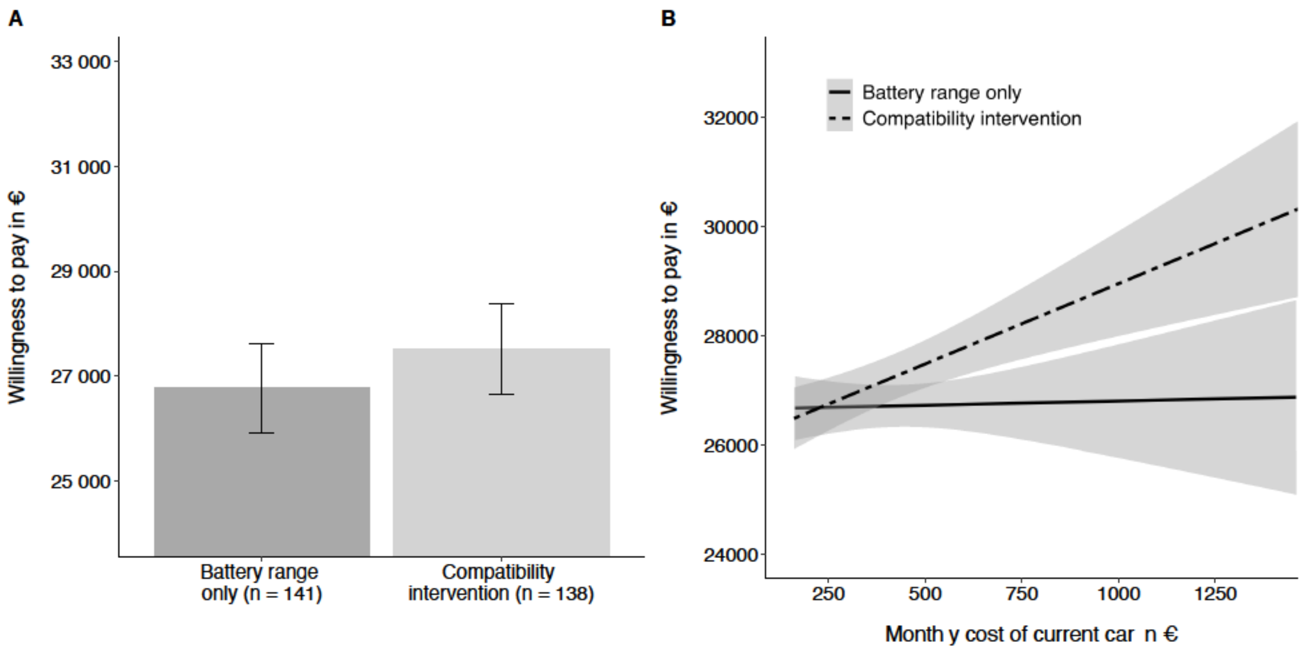

FIGURE 2: Main results from Study 2a with German car owners (N = 279). Panel A: Mean willingness to pay for a BEV by experimental condition. Providing compatibility information in addition to the battery range of BEV increased car owners' willingness to pay. Panel B: The interaction of the compatibility intervention with the total cost of car owners' current combustion engine car. Compatib lity information selectively increased willingness to pay for car owners with higher total cost of ownership while leaving BEV preference of car owners with lower current costs unchanged. Error bars and grey areas indicate 95% confidence intervals.

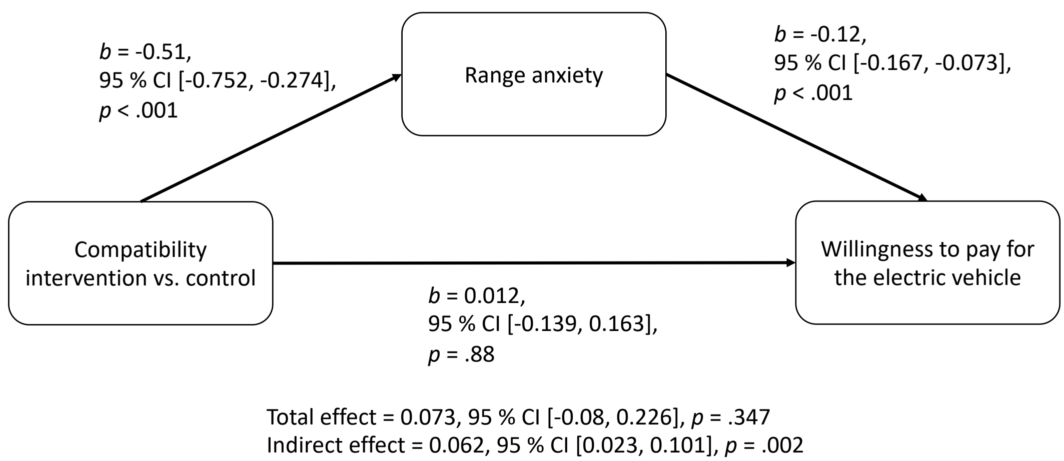

FIGURE 3: Mediation results of the relationship between the compatibility intervention and participants' willingness to pay, including range anxiety as a mediator on trial level. In line with our hypothesis, results supported range anxiety as a mediator. The effect of the compatibility intervention on willingness to pay was completely mediated by its impact on range anxiety, as suggested by the disappearance of the compatibility intervention effect on willingness to pay when accounting for range anxiety ($b = 0.012, 95\% CI[-0.139, 0.163]$, $p = .88$, 10,000 bootstraps). Coefficients and quasi-bayesian confidence intervals were estimated based on 10,000 bootstrap samples, using the *mediation* package for R [23].

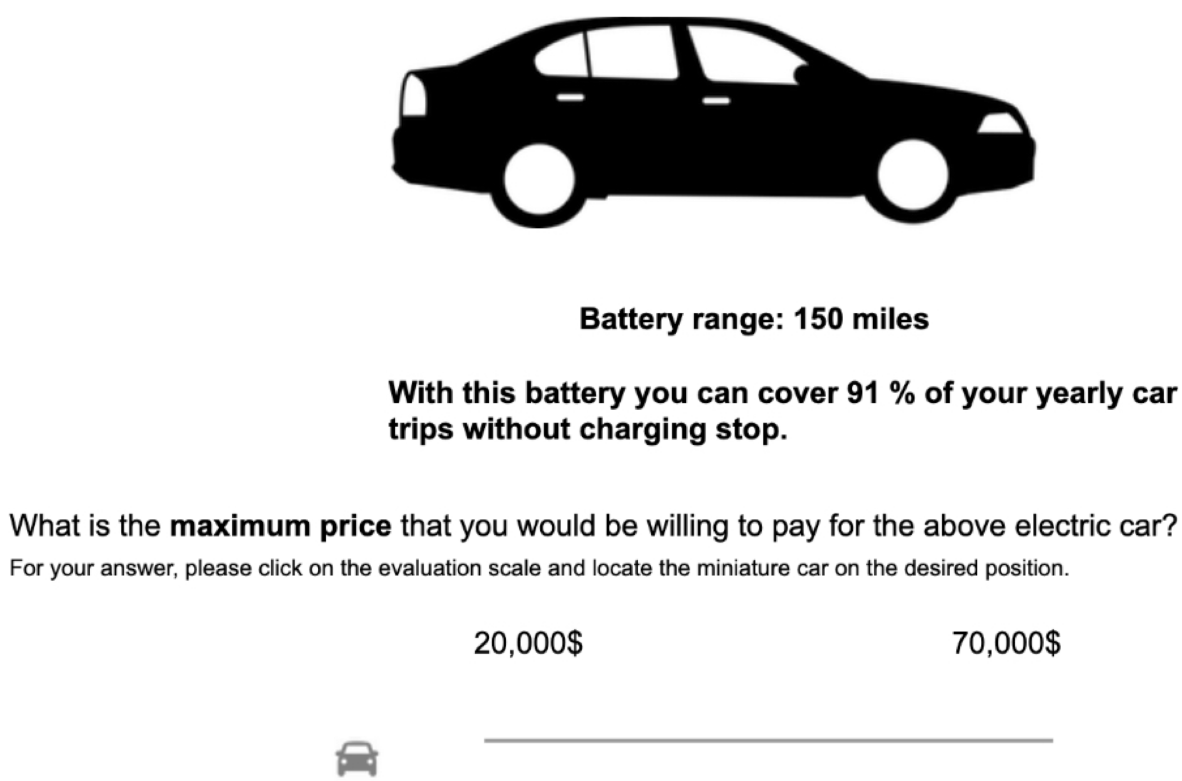

FIGURE 4: Example of the willingness to pay task in the compatibility condition in Study 2b. The only detail that differed between conditions was, that in the control condition a blank space was presented instead of the compatibility information and in the infrastructure condition the compatibility information was replaced by *With this car you have the right to use reserved parking with charging possibility in inner cities.*

TABLE 1: Study 1a sample characteristics of car owners before and after exclusion compared to German census data

Demographic variable	Level	German car owners* (in %)	Study 1a participants (*N* = 512; in %)	Study 1a participants after exclusion (*N* = 438; in %)
Sex	Men	51.7	51.6	51.4
	Women	48.3	48.4	48.6
Age	<29 years	15.2	15.3	15.3
	<39 years	16.2	17.1	17.1
	<49 years	17.3	23.1	17.1
	<59 years	21.4	13.5	23.1
	<69 years	15.3	14.0	13.5
	>70 years	14.6	15.3	14.0
Household income	< 1500€ per month	8.4	8.9	8.9
	< 2500€ per month	25.7	25.6	25.6
	< 3500€ per month	24.5	23.5	23.5
	< 4500€ per month	18.0	17.8	17.8
	> 4500€ per month	23.4	24.2	24.2

* Population statistics extracted from representative consumer research in Germany [24].
Exclusion of participants with unusable data (see Methods) was not significantly predicted by any of the demographic variables, preserving the representative nature of the remaining sample (b_{gender} = 0.02, $Z = -0.10, p = .93$; b_{age} = 0.01, $Z = 1.45, p = .146$; $b_{hhincome}$ = -0.01, $Z = -0.15, p = .88$).

TABLE 2: Study 1b sample characteristics of car owners before and after exclusion compared to U.S. census data

Demographic variable	Level	U.S. car owners* (in %)	Study 1b participants (N = 512; in %)	Study 1b participants after exclusion (N = 421; in %)
Sex	Men	49.4	49.8	51.5
	Women	50.6	50.0	48.2
Age	<29 years	20.4	18.0	18.5
	<39 years	17.4	18.4	19.2
	<49 years	16.4	16.8	16.2
	<59 years	17.6	17.8	17.1
	<69 years	15.4	16.2	15.9
	>70 years	12.9	12.9	13.1
Household income	< 25,000$ per year	16.7	13.7	12.8
	25,000$ to 49,999$ per year	22.6	24.0	23.8
	50,000$ to 74,999$ per year	18.5	20.1	21.1
	75,000$ to 124,999$ per year	24.4	25.6	25.2
	> 125,000$ per year	17.8	16.6	17.1
Ethnicity	Non-hispanic White	84.2	82.4	81.0
	Hispanic	6.9	6.6	7.1
	Black or African American	6.7	5.9	6.4
	Asian	3.7	5.5	6.2
	American Indian or Alaskan Native	0.6	1.2	1.4
	Pacific Islander	0.2	0.4	0.5
	Other	1.5	1.2	1.4
	Prefer not to answer	0.4	0.4	0.2

* Population statistics extracted from the U.S. National Household Travel Survey [12]. Exclusion of participants with unusable data (see Methods) was not significantly predicted by any of the demographic variables, preserving the representative nature of the remaining sample (b_{gender} = -0.34, $Z = -1.43, p = .152$; b_{age} = 0.002, $Z = 0.27, p = .79$; $b_{hhincome}$ = -0.08, $Z = -0.89, p = .38$; $b_{ethnWhite}$ = -1.73, $Z = -1.38, p = .169$; $b_{ethnHisp}$ = -2.07, $Z = -1.55, p = .120$; $b_{ethnAfrA}$ = -2.42, $Z = -1.74, p = .082$; $b_{ethnAsian}$ = -2.68, $Z = -1.43, p = .061$; $b_{ethnAIndian}$ = -15.8, $Z = -0.02, p = .986$; $b_{ethnNatHaw}$ = -12.1, $Z = -0.01, p = .994$; $b_{ethnOther}$ = -1.70, $Z = -0.02, p = .986$).

TABLE 3: Linear regression results of buying intentions and battery range requirements on perceived and actual compatibility instead of their difference (i.e., the compatibility bias), and demographic characteristics in the German (Study 1a) and U.S. sample (Study 1b).

	Study 1a		Study 1b		Study 1a		Study 1b	
Dependent variable	Buying intentions				Required battery range			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Intercept	4.16^{***}	3.41^{***}	3.48^{***}	3.25^{***}	360.94^{***}	321.98^{***}	256.61^{***}	259.41^{***}
Perceived compatibility	0.57^{***}	0.44^{***}	0.44^{***}	0.41^{***}	-40.84^{***}	-39.7^{***}	-22.35^{*}	-23.84^{*}
Actual compatibility	0.01	0.07	-0.35^{***}	−0.20	-28.31^{*}	−25.78	−9.84	2.34
Age		-0.56^{***}		-0.60^{***}		34.02^{**}		45.55^{***}
Gender		0.51^{**}		0.17		23.05		−9.78
Income		0.39^{***}		0.28^{**}		21.82		28.12^{**}
Yearly mileage		−0.05		−0.07		37.2^{**}		24.8^{*}
Access to public transport		0.25^{**}		−0.16		−10.19		7.52

Note. The dependent variable "intention to adopt an electric vehicle within the upcoming 10 years" was measured on a scale from 1 "Not at all" to 7 "Absolutely Yes". The dependent variable "Range required of a BEV to present an alternative to your current [combustion engine] car" was measured as numerical input in miles/km. The predictors Perceived compatibility and Actual compatibility were averaged across battery ranges within participants. Continuous predictor variables were Z-standardized. $^{***}P < .001$,$^{**}P < .01$, $^{*}P < .05$.

TABLE 4: Global model fits of random and fixed effects structures for the mixed-effects models used to analyse repeated outcomes in Study 2a and 2b.

Modelled outcome	Model	R syntax used	AIC	BIC
WTP in Study 2a	Random intercept	WTP ~ Condition x BatteryRange + (1|SubjectID)	36785.25	36818.71
	Random intercept and slope	WTP ~ Condition x BatteryRange + (BatteryRange|SubjectID)	35855.69	35900.3
	Fixed effects with interaction	WTP ~ Condition x BatteryRange + (BatteryRange|SubjectID)	35906.36	35950.98
	Fixed effects without interaction*	WTP ~ Condition + BatteryRange + (BatteryRange|SubjectID)	35904.4	35943.44
WTP in Study 2b	Random intercept	WTP ~ Condition x BatteryRange + (1|SubjectID)	140752	140806.8
	Random intercept and slope	WTP ~ Condition x BatteryRange + (BatteryRange|SubjectID)	135719.5	135788.1
	Fixed effects with interaction	WTP ~ Condition x BatteryRange + (BatteryRange|SubjectID)	135796.8	135865.3
	Fixed effects without interaction*	WTP ~ Condition + BatteryRange + (BatteryRange|SubjectID)	135803.8	135858.6
Range anxiety in Study 2b	Random intercept	RangeAnxiety ~ Condition x BatteryRange + (1|SubjectID)	21636.43	21691.25
	Random intercept and slope	RangeAnxiety ~ Condition x BatteryRange + (BatteryRange|SubjectID)	19566.58	19635.11
	Fixed effects with interaction*	RangeAnxiety ~ Condition x BatteryRange + (BatteryRange|SubjectID)	19542.68	19611.2
	Fixed effects without interaction	RangeAnxiety ~ Condition + BatteryRange + (BatteryRange|SubjectID)	19556.76	19611.59

Note. Appropriateness of the random effects structure was determined based on the Akaike's and Bayesian information criterion (AIC and BIC), estimated using the restricted maximum likelihood method and including all potential fixed effects. The selection of fixed effects was determined based on AIC and BIC, using maximum likelihood estimations [25]. Lower AIC and BIC values indicate better model fit of competing random or fixed effect structures. When AIC and BIC did not point into the same direction, lower BIC values received more weight for the model selection, favoring more parsimonious models in line with the principle of Occam's Razor. Selected models are signaled with an *.

Supplementary Methods

Study 1 Stimuli

Wordings in English from Study 1B. German versions from Study 1A are available upon request.

Demographics

What is your age?
What is your gender? (*woman; man; other; prefer not to answer*)
Please choose one or more ethnicity that you consider yourself to be. (*non-Hispanic White; Hispanic; Black or African American; Asian; American Indian or Alska Native; Nativa Hawaiian or PaAcific Islander; Other; I prefer not to answer)*
How high is your annual household income before taxes? (*less than 25,000$; 25,000$ to 49,999$; 50,000$ to 74,999$; 75,000$ to 99,999$; 100,000$ to 124,999$; 125,000$ and more*)
Do you own a car? (*Yes; No*)
To what extent is your home connected to public transport services that provide alternatives to the use of your car? (*1: Very well connected - 7: Not connected at all*)

Purchase intention and required battery range

To what extent do you consider buying an all-electric vehicle in the upcoming 10 years? (*1: Not at all - 7: Absolutely Yes*)
What is the battery range of an all electric vehicle that you would require, to consider it an alternative to your current combustion engine car [*in miles*]?

Perceived compatibility

In the following we would like to ask you to estimate the share of your car trips in 2019 that you could have covered with an all-electric vehicle without recharging.

An all-electric vehicle is exclusively powered with the energy from its built-in battery. Car trips means all one-way car trips (i.e. outward and return trip counted separately), completed with you as the driver.

Please report below the percentage of your total car trips in 2019 that you think you could have covered with the respective electric vehicles and battery ranges:

All-electric vehicle with a battery range of 50 [60, 90, 120, 150, 180, 210, 240] miles. (*0%: non of your trips feasible - 100%: all of your trips feasible*)

Attention check

To show that you are carefully reading the instructions of this survey, please do not select any of the following options and click „Next“ to continue the survey. (*Soccer, Holidays, Beach, Dancing, Biking, Mountains*)

Driving distances

Please think about the car trips that you completed throughout the year 2019. How often did you complete car trips of the following distances?

Please take your time and answer this question carefully: Think about short, daily trips, as well as longer trips like for example for vacation.

Supportive information: A year has 52 weeks with 5 work days each. Official federal holidays are New Year's Day, Martin Luther King Day, Memorial Day, Independence Day, Labor Day, Columbus Day, Veterans Day, Thanksgiving, and Christmas.

Please note: Count outward and return trips separately - if you drove, for example, 15 miles to your workplace on 260 workdays, please indicate the number 520 in the answer field next to "10 to 20 miles". Please indicate "0" if you never traveled a given distance.

Trip distance shorter than 0.5 mile [0.5 mile to < 1 mile, 1 mile to < 2 miles, 2 miles to < 5 miles, 5 miles to < 10 miles, 10 miles to < 20 miles, 20 miles to < 30 miles, 30 miles to < 60 miles, 60 miles to < 90 miles, 90 miles to < 120 miles, 120 miles to < 150 miles, 150 miles to < 180 miles, 180 miles to < 210 miles, 210 miles to < 240 miles, 240 miles and longer]: (*Number of one-way car trips in 2019*

Comment

Do you have any comment with respect to this study? If not, please click on "Next".

Study 2 Stimuli

Wordings in English from Study 2B. German versions from Study 2A are available upon request.

Demographics

What is your age?
What is your gender? (*woman; man; other; prefer not to answer*)
What is your mother tongue?
Do you own a car? (*Yes; No*)

Information about current car

How old is your car [*in years*]?
What is the original purchase price of your car, when it was new [*in $*? (the original purchase price might deviate from the price you paid for the car, for example if you purchased it used)
How much does your car consume [in miles per gallon]?

Attention check

To show that you are carefully reading the instructions of this survey, please do not select any of the following options and click „Next“ to continue the survey. (*Jeep, Ford, Toyota, Chevrolet, Mercedes Benz, Honda*)

Driving distances

Same as in Study 1.

Instructions of the willingness to pay task

Please assume that you have decided to replace your car with an electric car. You have already decided which model you would like. However, this model is available with different batteries that allow for different maximal driving ranges of the vehicle.

The basic model has a driving range of 50 miles with one battery charge and costs 20,000$. For a price premium you can purchase a larger battery that allows for a longer driving range. In all other aspects, the car configurations are identical.

Please indicate how much you would be willing to pay for each of the models with improved driving range.

[Page break]

Please indicate on the following pages the maximum price that you would be willing to pay for a configuration with a longer driving range. In total, 7 configurations with different driving ranges will be displayed.
[Compatibility condition] Additionally, you will be presented with the percentage of annual trips that you can make with the respective battery configuration without charging stop. This information is calculated specifically for you, based on your reported car trips throughout a year.
[Infrastructure condition] Additionally, you will be provided with information on your right to use reserved parking with a charging possibility in inner cities. Reserved parking with a charging possibility is an increasingly common measure applied by local governments to facilitate the use of electric vehicles.

Here, as an example the display of the basic model for 20,000$ [with a battery range of 50 miles]:

Willingness to pay task

(see Supplementary Figure 4 for a screenshot of the task)

Battery range: 60 [90, 120, 150, 180, 210, 240] miles
[Compatibility condition] With this battery you can cover [...] % of your yearly car trips without charging stop.
[Infrastructure condition] With this car you have the right to use reserved parking with charging possibility in inner cities.
What is the maximum price that you would be willing to pay for the above electric car? (*20,000$ to 70,000$*)

Range anxiety measure

[Repeat stimulus presentation from WTP measure]
When driving the above car, to what extent would you be worried to run out of battery before reaching your destination? (*1: Not worried at all - 7: Very much worried*)

Attention check

To show that you are carefully reading the instructions of this survey, please do not select any of the following options and click „Next“ to continue the survey. (*Washington, Texas, New York, California, Philadelphia, Florida*)

Accuracy of battery range information

Do you believe that the information you received on the driving range of electric vehicles is accurate and that it reflects the driving range that you would be able to complete when actually driving? Note: Like information on gas mileage, the battery range of electric vehicles is determined under standardized conditions that can not account for all variations in real life driving. (*1: Not accurate at all - 7: Absolutely accurate*)

Comment

Do you have any comment with respect to this study? If not, please click on "Next".

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