How to increase the willingness to buy small and low-range battery electric vehicles

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Abstract

More than half of new vehicle registrations are categorized as a large car in many countries and people still expect battery electric vehicles (BEV) to perform similar to conventional cars regarding driving range. Yet, smaller cars with a smaller battery would be sufficient for typical daily distances and could reduce greenhouse gas emissions, consumption of raw materials and pedestrian fatalities. I applied a within- and between-subject design study with 1000 participants from the German- and French-speaking population of Switzerland, testing the provision of information about typical range requirements and charging station availability on the potential to influence participant's vehicle choice preference. The results suggest that providing information about typical range requirements and having access to charging stations at home could be a promising lever to increase the switch from conventional cars and high range BEVs to lower range BEVs. The results are relevant for transport planners and politicians in designing efficient strategies to decrease the trend towards increasing size and range requirements for BEVs.

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Battery electric vehicle, car size, choice experiment, charging, carsharing, policy

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1 Introduction

The market share of large vehicles is growing around the globe. With the aim to limit global warming well below 2°C by the end of the century, electrifying the passenger car sector is one of the low hanging fruits identified by research, policy makers and car manufacturers (Sacchi et al., 2022; Zhang & Fujimori, 2020). Battery electric vehicles (BEV) are suitable for the majority of passenger car use cases (Herberz et al., 2022). Yet, people still expect BEVs to deliver a similar range as conventional gasoline and diesel cars (Kowalska-Pyzalska et al., 2022). This is reflected by car manufacturers producing new BEVs models with increasing range, which are typically also larger. Around 60% of available BEV models in China and Europe belong to the SUV and large car category (International Energy Agency, 2023). This is even surpassed by USA where 80% of all available BEV models belong to these categories (International Energy Agency, 2023). While this allows BEVs to be competitive with conventional cars regarding range, it poses several problems. In 2022, the sales-weighted average battery size of small BEVs ranged from 25 kWh in China to 35 kWh in Europe, and about 60 kWh in the United States. In comparison, the sales-weighted average battery size for large and SUV BEVs was around 70-90 kWh in these countries (International Energy Agency, 2023). This leads to an increased weight of the car, which not only increases emissions of particulate matter from abrasion of tires, but also energy demand and accident severity (Ellingsen et al., 2016; Franzò & Nasca, 2021; Tyndall, 2021). Further, the larger battery increases the demand for raw materials in producing the batteries, increasing potential supply-chain shortages (Karabelli et al., 2020).

Despite these issues stemming from large cars and high battery capacities, so far, very few research focused on how to decrease the need for range in BEVs, thus reducing the battery capacity and the aforementioned negative effects.

Hoerler et al. (2023) find that having the possibility to charge a BEV at home could increase the uptake of a small, low-range BEV from previously owning a conventional car. Further, providing information about range compatibility was shown to increase BEV adoption (Bernadic et al., 2024). Thus, a combination of these two measures seems to be a promising intervention to reduce the need for a large and high range BEV. While Hoerler et al. (2023) investigated a similar research question, their set of alternatives in their choice experiment was limited to three predefined mobility lifestyles, neglecting different preferences regarding car size and powertrain in the automotive market. To fill this gap, I incorporated an online-experiment testing the preference for car size and powertrain choice in a hypothetical scenario, where current conventional car owners have to replace their car.

I therefore ask the following research question:

Can the provision of information about daily range needs in combination of access to charging stations at home increase the uptake of smaller and low-range BEVs as the next vehicle replacement?

In the next section, I explain the survey sample, questionnaire structure and the applied statistical methods. This is followed by Section 3 containing the results and finally, the discussion with concluding remarks in section 4

2 Methodology

2.1 Survey sample

I conducted an online-experiment using a within- and between-subject design study within the German- and French-speaking population of Switzerland. The survey was administered through the marketing research company Respondi. I ensured to have a representative sample for the Swiss population through quotas on gender, age and language region. The target sample were people aged at least 18 years and a maximum of 80 years, who own a car or, if living in a household with several people, use the car the most within the household. In total, I received 2467 respondents of which 1465 were screened-out due to a quality check. Finally, a sample of 1002 respondents reached the end of the survey.

The following table displays the differences between the sample and the Swiss population for a set of socio-demographic and mobility related variables.

Table 1: Study sample compared to the Swiss population.

Variable	Level	Study (n = 1’002)	Swiss population	Difference Study / Swiss population

Age[1]	(mean)	48.37	51.28	$t(998) = -31.21$, $p < 0.001$
Gender[2]	Male	54.4%	49.4 %	χ2 (1, N = 1002) = 9.79, $p = 0.002$
	Female	45.6%	50.6 %	
Region[3]	German	73.5%	73.2%	χ2 (1, N = 1002) = 0.33, $p = 0.856$
	French	26.5%	26.8%	
Household car ownership	1	55.4%	54.1%	χ2 (1, N = 1002) = 0.67, $p = 0.413$
	2 or more	44.6%	45.9%	

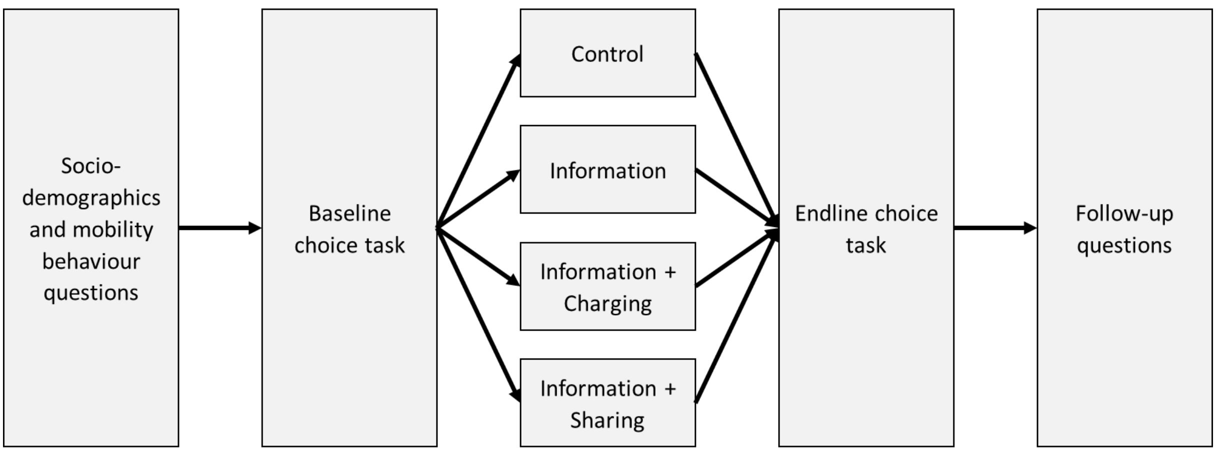
[1]Swiss Federal Statistical Office (2021a), [2]Swiss Federal Statistical Office (2021d), [3]Swiss Federal Statistical Office (2021b), [4]Swiss Federal Statistical Office (2021c), [5]BFS and ARE (2017)

Due to the dropouts from the quality-check, I have a slightly younger sample and a small overrepresentation of men compared to the Swiss population. Region and household car ownership do not differ from the Swiss population.

2.2 Online-experiment survey

I structured the online-experiment survey in five parts: 1) socio-demographics and mobility behaviour questions, 2) baseline choice task, 3) treatment, 4) endline choice task and 5) follow-up questions. Figure 1 provides an overview of the survey structure. Each participant filled in the mobility behaviour questions and the baseline choice task, was then randomly assigned to one of the treatment groups (control, information, information + charging, information + sharing), conducted the endline choice task and finally the follow-up questions. In this paper, I only focus on the information + charging treatment.

Figure 1: Overview of the survey structure.



Own illustration

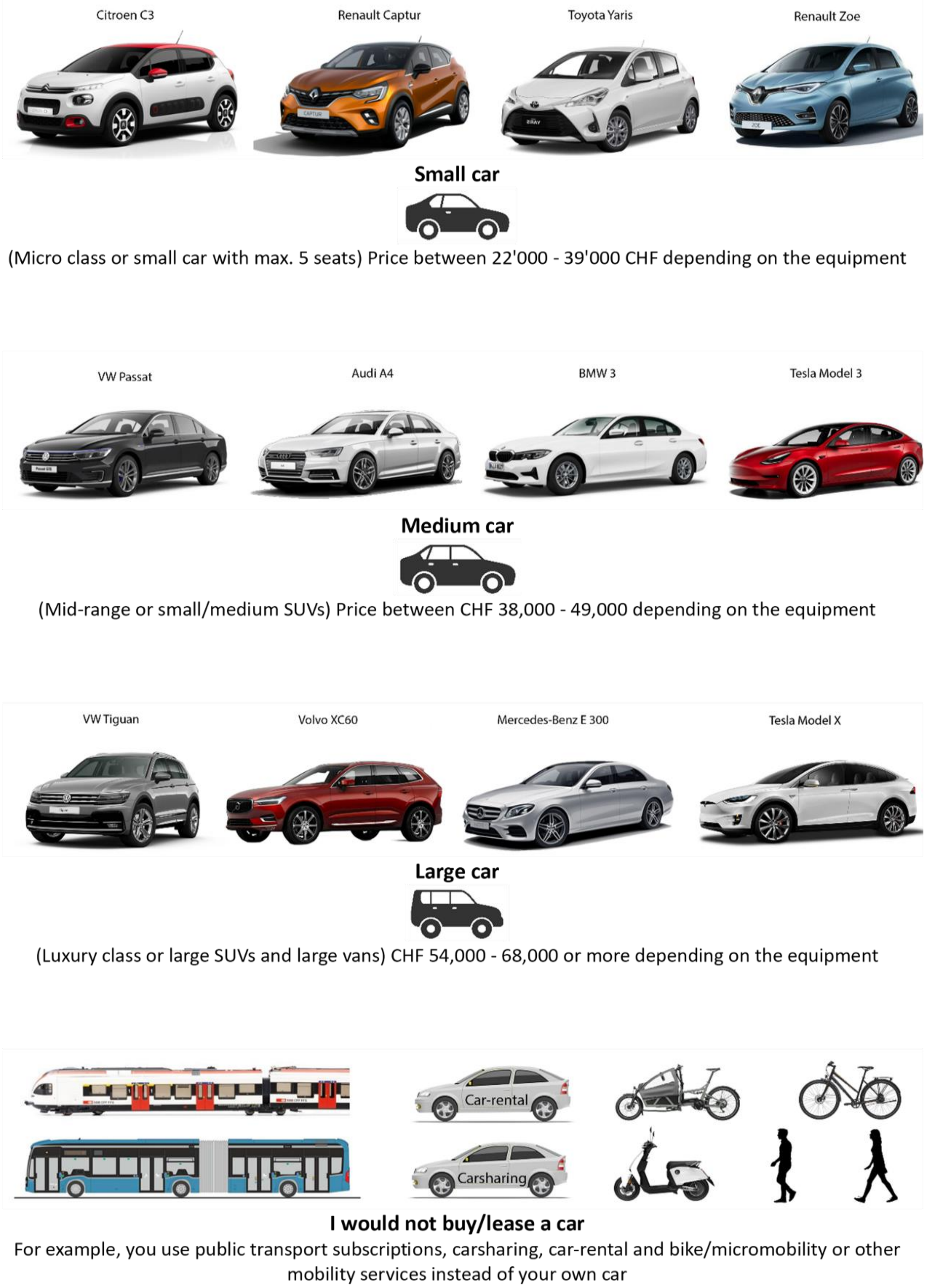
2.2.1 Socio-demographics and mobility behaviour questions

In this first part of the survey, questions about gender, age, household structure and income were asked to be able to set quotas for a representative sample of Swiss car owners. In addition, several questions focused on the mobility behaviour of the respondents. These include: car ownership, powertrain of the main household car, car size of the main household car, number of kilometers driven per year with the main household car, number of overnight trips exceeding 200km one-way per year, number of daytrips exceeding 200km per year, public transport usage and experience with mobility services (carsharing and car rental).

2.2.2 Baseline choice task

In the baseline choice task, respondents were put in a scenario, where their most used car (main household car) breaks down and cannot be repaired anymore. They should then think whether they would buy or lease a car again and what size they would prefer. The respondents were given three car size options (small, medium, large) and an alternative without buying a car. Each option contained a short description of an approximate price-range and examples of well-known car models. In order to make the car buying process as tangible and relatable as possible, I used real pictures of different cars. This increases the salience and ecological validity of the car buying scenario respondents should put themselves into (Bordalo et al., 2022; Schmuckler, 2001). Figure 2 depicts the four choice possibilities as shown to the participants.

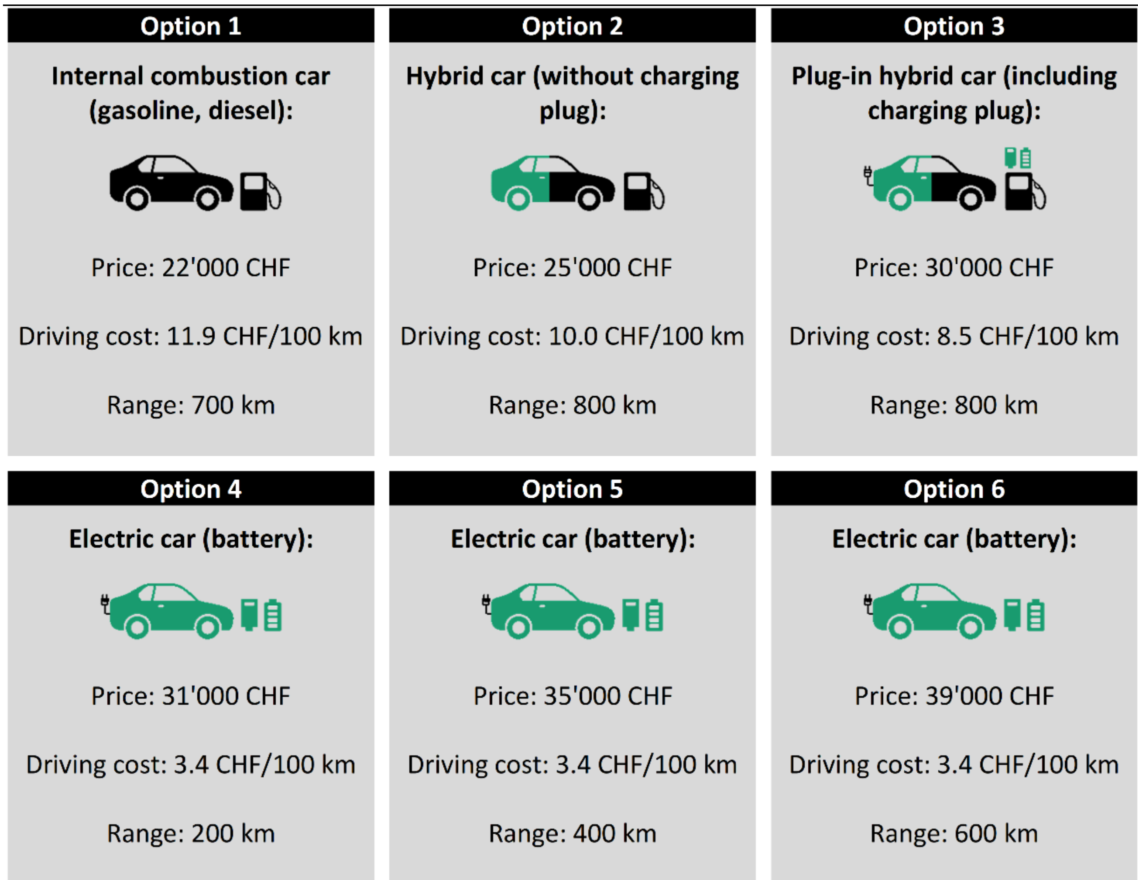
Figure 2: Depiction of the four possible replacements of the participant's current main car. Respondents had to click on one of the four options.



Own illustration

Participants who chose one of the three car size options, were then shown a powertrain choice question including six different car options as shown in Figure 2. The information provided was tailored to the car size chosen before. The price, driving cost and range values were derived from ADAC - General German Automobile Club, based on average values of car models in the small size segment, medium size segment and large segment (ADAC, 2022). One advantage of the dataset by ADAC is that they make pairs of similar cars regarding power, number of doors, storage space for conventional cars, hybrid cars PHEVs and BEVs. This leads to an increased comparability of the different powertrain options and transferability from hypothetical research to practice.

Figure 3: Powertrain choice options, tailored to either “small”, “medium” and “large” car size chosen in the previous question. Example for the category “small”.



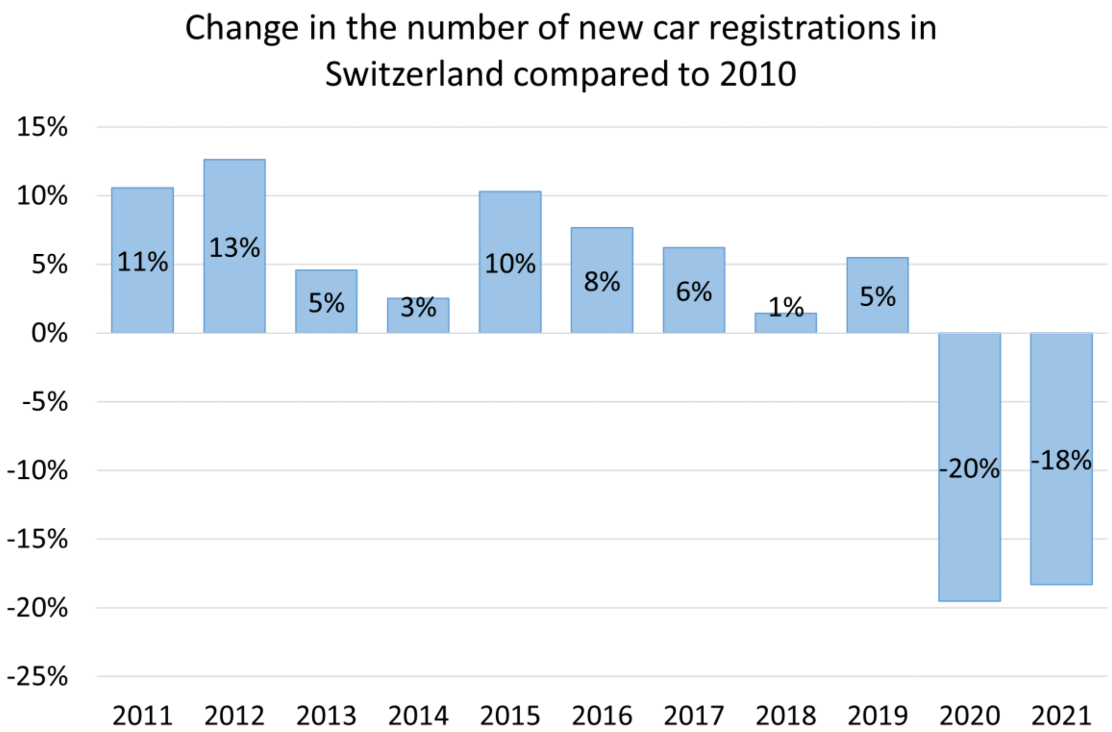
Own illustration

The respondents of the survey then had to indicate which of the six options would be their first, second and third-most preferred choices as a replacement of their current main household car.

2.2.3 Treatment

Respondents were randomly assigned to either the control treatment, information treatment, information + charging treatment or information + sharing treatment. Respondents in the control group received a placebo information, that intends not to influence the choices. They were given information regarding the drop of new car registrations due to the corona pandemic. This information was further displayed as a figure as shown in Figure 3. For the complete treatment text, refer to Table 2 in the appendix.

Figure 4: Graphical depiction of the information provided to the control group.

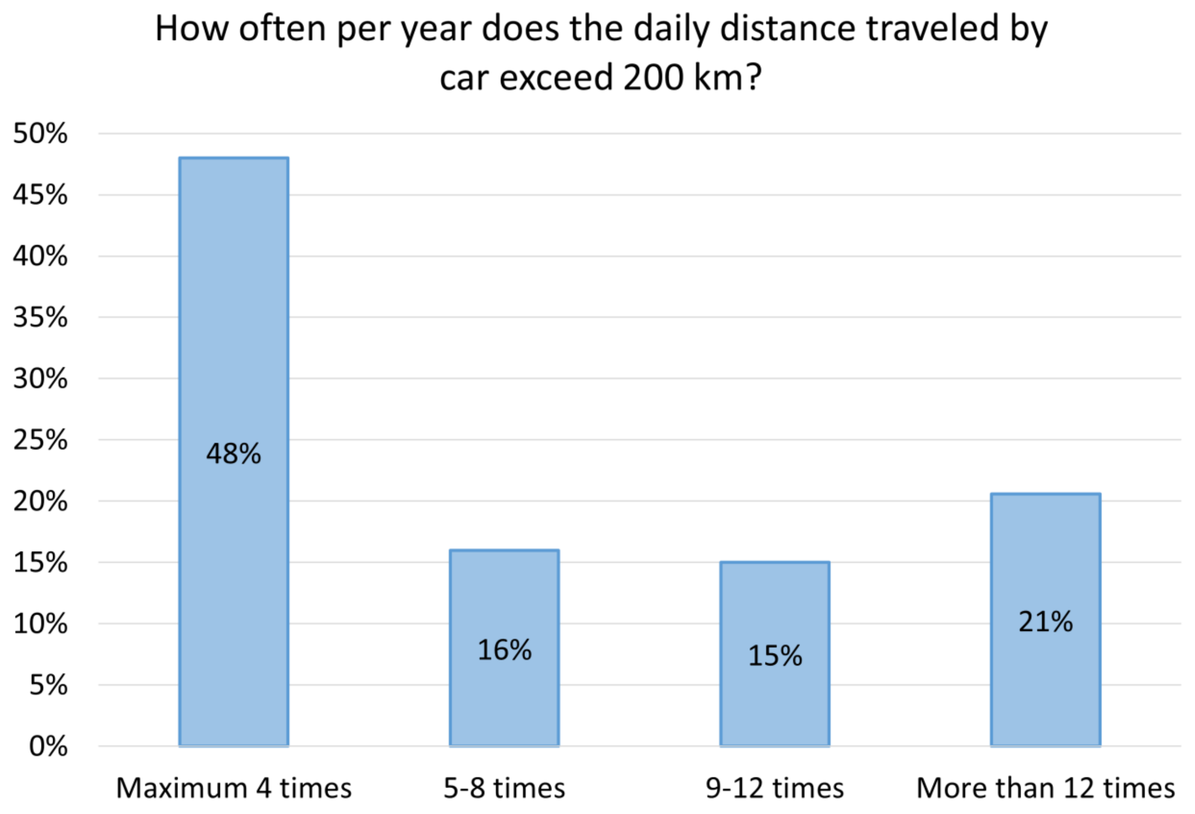


Own illustration

The information text and figure were followed by a quality check in the form of one question. In the case of the control group, the question was as follows: “How much have new car registrations decreased in 2021 compared to 2010?” Respondents then had to write the number in a text field. If they didn’t write the correct answer (-18%), they were screened out. This test ensured that I only include respondents in the final analysis who read the treatment text.

In contrast to the control group, the information + charging treatment group received information about the average times a year, Swiss household conduct car trips above 200 km. Further, information about the potential of charging at home and carsharing to complement a small BEV was given. This information treatment was intended to increase the choice of smaller, low-range BEVs in the endline choice task, since people underestimate the compatibility of available BEV range with their annual mobility needs (Herberz et al., 2022). In addition, respondents should imagine a scenario, where they have a charging station at home and can easily charge a BEV overnight or during the day, even if they don’t have a garage space at home. This treatment ensures that the respondents would be able to have a fully charged car in the morning, if charged overnight, addressing a key driver in BEV adoption (Khatua et al., 2023). Again, the complete treatment text is available in Table 2 in the appendix. The following figure was given to the information + charging treatment group (Figure 5).

Figure 5: Graphical depiction of the information provided to the information + charging group



Own illustration

As with the control group, I included a quality check, where respondents had to answer the following question: “What percentage of Swiss car users travel more than 200 km on a maximum of 4 days a year? If they did not write the correct answer (48%), they were screened-out. After the treatment text, the respondents were shown the endline choice task.

2.2.4 Endline choice task

Respondents were asked to do the same questions again regarding car size and powertrain choice. If respondents opted to not replace their current main car (choosing the “no car” option), they were directed to the follow-up questions. Participants of the control group who chose one of the three car size options, were then shown the same powertrain choice options as in the baseline choice question. In contrast, the respondents of the information + charging treatment group further received a small text (“Guaranteed charging option at home”), reminding about the charging treatment as shown in Figure 6. This increases the salience of the treatment in the choice process.

Figure 6: Overview of the six powertrain options as shown to the participants (information + charging treatment).

Option 1	Option 2	Option 3
Internal combustion car (gasoline, diesel):	**Hybrid car (without charging plug):**	**Plug-in hybrid car (including charging plug):**
Price: 22'000 CHF	Price: 25'000 CHF	Price: 30'000 CHF
Driving cost: 11.9 CHF/100 km	Driving cost: 10.0 CHF/100 km	Driving cost: 8.5 CHF/100 km
Range: 700 km	Range: 800 km	Range: 800 km
-	-	Guaranteed charging option at home

Option 4	Option 5	Option 6
Electric car (battery):	**Electric car (battery):**	**Electric car (battery):**
Price: 31'000 CHF	Price: 35'000 CHF	Price: 39'000 CHF
Driving cost: 3.4 CHF/100 km	Driving cost: 3.4 CHF/100 km	Driving cost: 3.4 CHF/100 km
Range: 200 km	Range: 400 km	Range: 600 km
Guaranteed charging option at home	Guaranteed charging option at home	Guaranteed charging option at home

Own illustration

As in the baseline choice, respondents were asked to indicate their first priority, second priority and third priority replacing their current main household car.

2.3 Statistical analysis

I conducted several checks to ensure high quality of the data. In order to test for outliers, I used standardized values of the variables "number of daytrips exceeding 200 km per year" and "number of overnight trips exceeding 200 km per year" asked in the first part of the survey. I further calculated the Cook's distance with the dependent variable "number of overnight trips exceeding 200 km per year" (Cook, 2000). Through manually checking the seven identified outliers, I removed two from the dataset. I further checked all respondents who used less than 3 minutes in filling in the questionnaire, finding no signs of illogical answers. As such, I remained with 1000 respondents for the analysis.

For both choice task (car size and powertrain), a within- and between-subject effect can be measured, as I have data from the baseline choice and endline choice for each respondent and each treatment group.

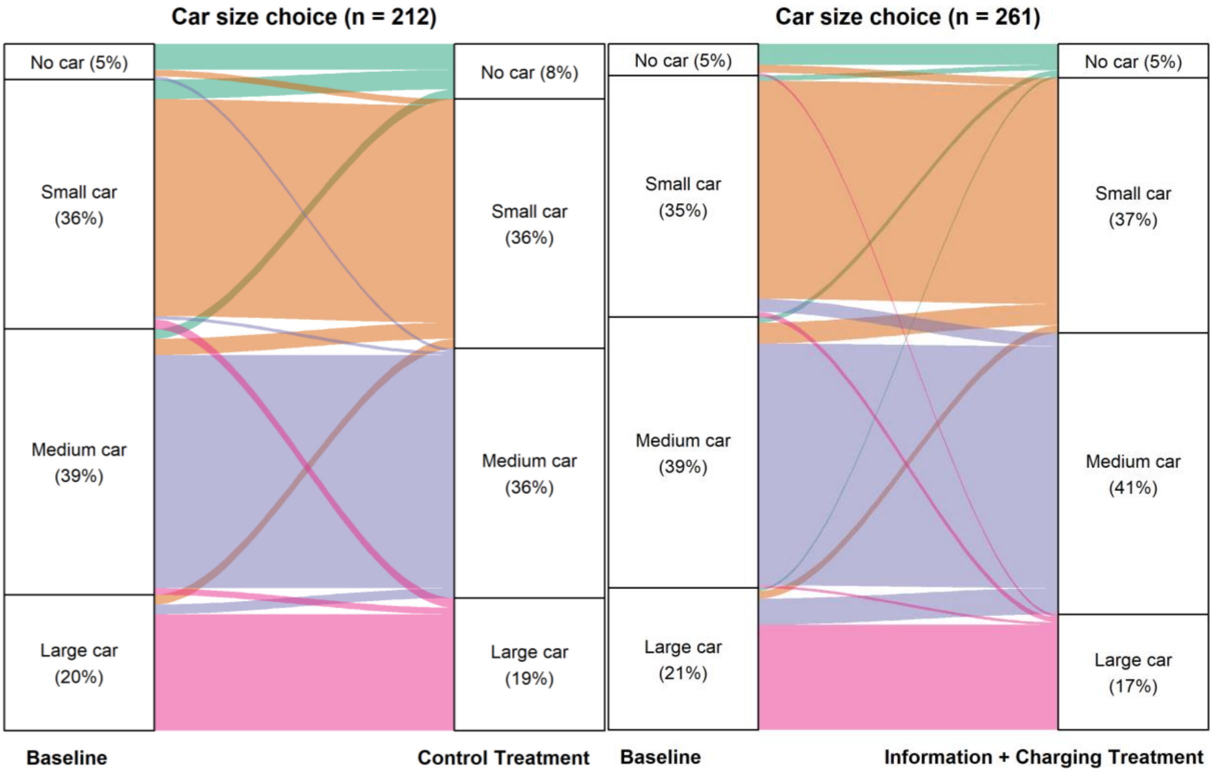
Since respondents had to indicate their first, second and third most-likely option to replace their current main car, I could calculate ranks for each of the six options displayed. While the first choice is coded as a rank of 1, the second choice as 2 and the third choice as 3, if an option was not chosen at all, it would receive a rank of 4. I used the Wilcoxon Signed-Rank Test to compare the endline choice rank to the baseline choice rank (within-subject) and the Mann-Whitney U Test to compare the treatment groups to the control group (between-subject).

3 Results

3.1 Car size choice

For a first descriptive overview, Figure 7 shows the car size choice for the control treatment group and the information + charging treatment group. The first column corresponds to the baseline choice, whereas the second column shows the endline choice influenced by the treatment condition.

Figure 7: Alluvial plot of the changes between baseline choice and endline choice of the control treatment group (left) and the information + charging treatment group (right).



Own illustration

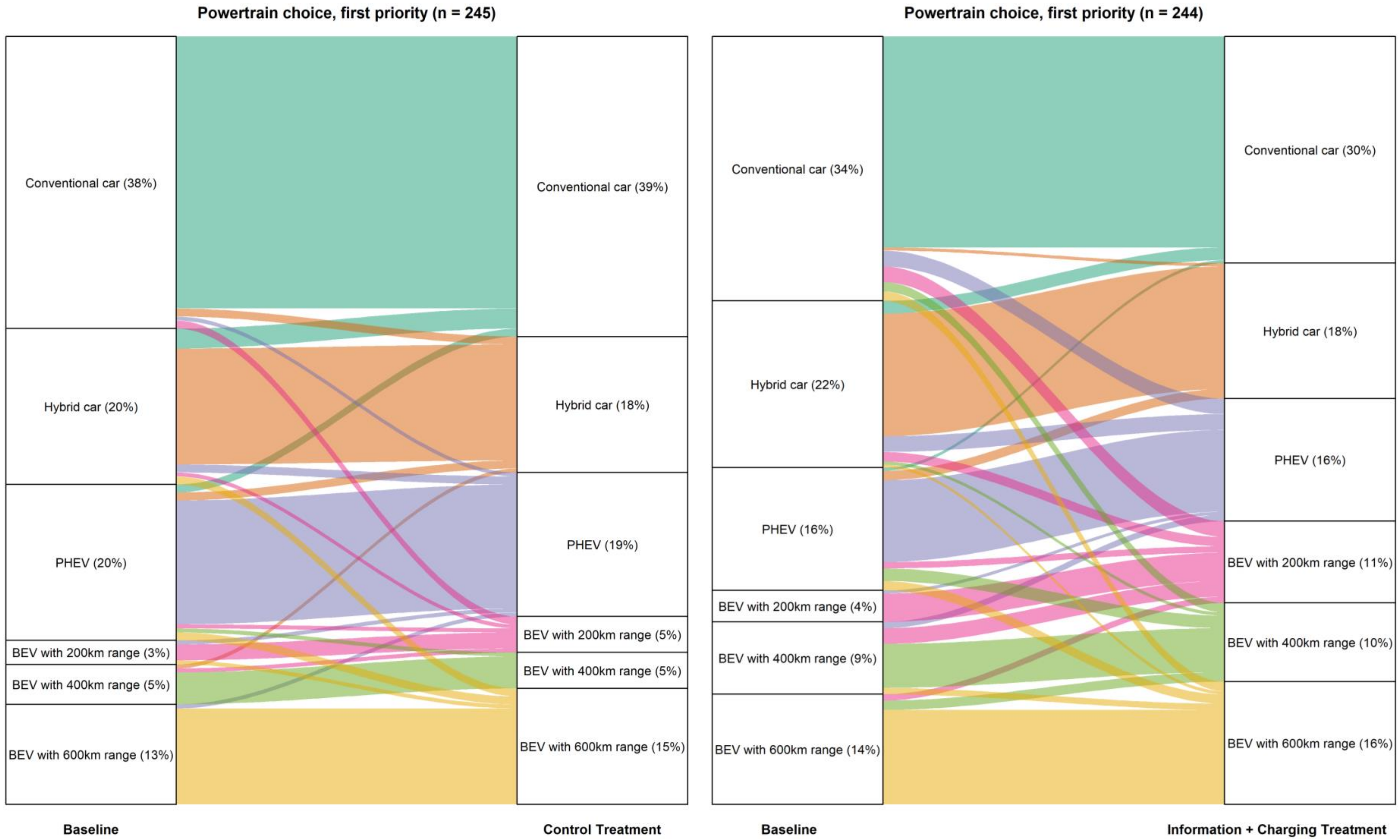
People would most likely opt for a small or medium-sized car as their next car replacement. The majority of respondents stay within the same size category, both in the control condition and the information + charging treatment condition. Still, some changes are observable, for example, a larger switch from a large-sized car to a medium-sized car in the information + charging treatment group compared to the control treatment group. The Wilcoxon Signed-Rank Test for within-subject effects supports this observation as we see a significant smaller average car size chosen between the baseline choice and the endline choice for the information + charging treatment group ($Z = -2.027$, $p = 0.043$, $n = 522$). In contrast, no significant difference was found for the control treatment group ($Z = -1.564$, $p = 0.118$, $n = 424$). Therefore, I am confident that the effect stems from the treatment and not from a desirability bias due to the questions and repeated nature of the experiment (Gittelman et al., 2015). According to the guideline by Funder and Ozer (2019) , the effect can be considered a very small effect ($r = 0.089$).

3.2 Powertrain choice

An overview of the first priority of the powertrain choice is shown in Figure 8. Most people (38%) would opt for a conventional car to replace their current main household car in the baseline choice of the control group. Also in the baseline choice of the treatment, the majority of respondents would choose a conventional car (34%). Only very few would opt for a BEV with 200 km range in the baseline choice in both conditions (control = 3%, information + charging treatment = 4%). In the endline choice, however, people switch much more often to the BEV with 200 km range option in the information + charging treatment (11%) compared to the control treatment (5%). Note that Figure 8 only shows the switching behaviour of the first priority in the powertrain choice task. The following tests, however, are based on the ranks of the different powertrain options, since respondents had to indicate their first, second and third priority.

The Wilcoxon Signed-Rank Test for within-subject effects shows that the difference between the baseline and the endline choice of the information + charging treatment group is significant ($Z = -4.802$, $p < 0.001$, $n = 488$). This effect can be considered a medium-sized effect ($r = 0.217$). Again, I compare the within-subject results with the control group ($Z = -0.371$, $p = 0.711$, $n = 384$), ensuring that the significant effect from the information + charging treatment does not stem from a social desirability bias.

Figure 8: Changes between baseline choice and endline choice of the control treatment group (left) and the information + charging treatment group (right) for the first priority in the powertrain choice question, own illustration.



4 Discussion and conclusion

Through a within- and between-subject design online-experiment, I was able to show shifts in car buying preferences by informing car owners about the typical range requirements during the year in combination of secured access to a BEV charging station. The results show that the preference for a large car as the next car replacement could be reduced. A further benefit is that people would switch from conventional cars and high range BEVs (600 km range) to a BEV with a lower range (200 km). These shifts in car buying preference, if it also leads to actual behavior, could reduce several negative externalities stemming from large cars (including BEVs) and conventional cars.

The findings could help decision makers and mobility planners in their effort to reduce greenhouse gas emissions from transport, accident severity, supply-chain shortages and space occupation in urban areas. Especially considering the growing population of urban and sub-urban conurbations, where space is scarce and the installation of charging stations not as straight-forward as compared to rural areas characterized by home-owners, clear guidelines and targets about charging station availability for tenants are important. Site managers could embrace the findings of this paper to accelerate and facilitate access to secured BEV charging for the residents potentially fostering a switch from conventional cars to BEVs. They could further provide general advice and information about alternatives to the personal car for specific use-cases, for example, when the range of a small BEV (200 km) would not be sufficient or not as convenient. This might include advice on car-rental services for holiday trips or carsharing for trips to move large luggage (e.g. furniture). Fostering experience with these mobility service could increase the openness to switch to BEVs as they could reduce some of the main concerns such as range anxiety (Hoerler et al., 2021).

The findings of this study could also be incorporated into policy-packages that target to reverse the trend towards larger cars in Europe, a target that has also been recognized by other research (e.g. Gómez Vilchez et al., 2023) and is helpful to meet the climate goals pledged by European countries.

While stated choices in controlled experimental settings are frequently employed to study the adoption of new energy-efficient technologies and products, these findings may not accurately reflect real-world choices due to the significant financial implications and hypothetical bias involved (Haghani et al., 2021). Therefore, I advocate for future studies that examine revealed preferences to validate my findings. Given that information provision could be integrated into communication campaigns of policymakers and site managers, such field studies could be feasible.

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A Appendix

A.1 Appendix Tables

Table 2: Overview of control and treatment text shown to the participants

Baseline choice text Please imagine the following situation: Your most used car (main car) breaks down within this year and can no longer be repaired. In this context, we ask you whether you would buy/lease a new car and what size/drive your preferred car would be. Based on the information shown below, please select the size category that is most likely to replace your main car. The car models shown are examples of the size class. Make this choice carefully, as the upcoming scenarios will only focus on this preferred vehicle type/size. Make your decisions as if you were actually buying/leasing a new car, taking into account your budget and preferences. For the decisions in the following questions, assume that the charging infrastructure for electric cars, the density of car sharing stations and the options for car rental (e.g. Hertz, Avis, Europcar) are the same as today. In the next question, we ask you to decide which car you would choose to replace your main car. You have the choice between 4 drive types. The car options are indicated with the purchase price, driving costs per 100 km and range and are based on the previously selected car size. Assume that, in addition to the costs and range described, the car options shown meet your requirements in terms of interior equipment, number of doors, trailer coupling, etc. in exactly the same way. Manufacturers offer different range models of the electric car. Depending on the range, the price and environmental impact will increase accordingly. We would like you to choose your 3 preferred options from the table. Decide in each case as you would in real life, taking into account your preferences and budget.

Control Treatment text

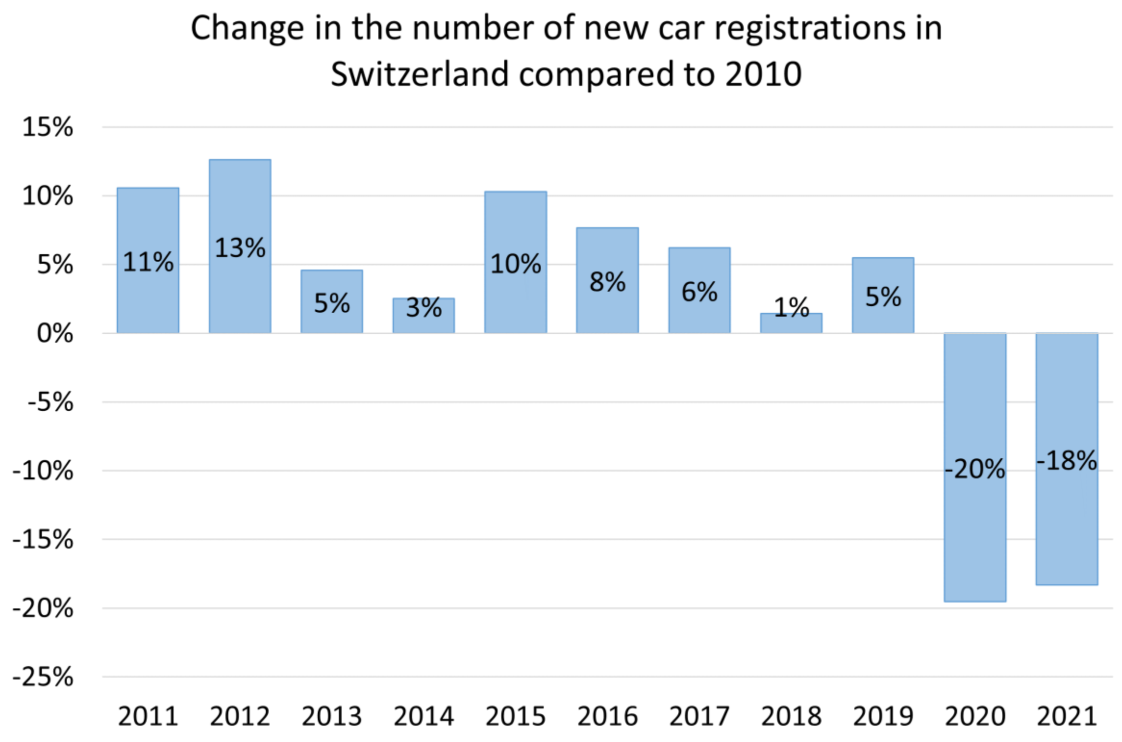
In the next part of the study, you will have the opportunity to find out more about Swiss mobility behavior and developments. We will provide you with information on the following question:

- What is the proportion of new car registrations in Switzerland compared to 2010?

The discussion will be followed by a quiz with one question. Please follow the discussion carefully so that you can answer the quiz question correctly.

New car registrations did not change significantly between 2010 and 2019, fluctuating between +1% and +13%. However, the sharp decline in 2020 and 2021 is striking. The coronavirus pandemic is the main reason for the sharp drop in deliveries in 2020.

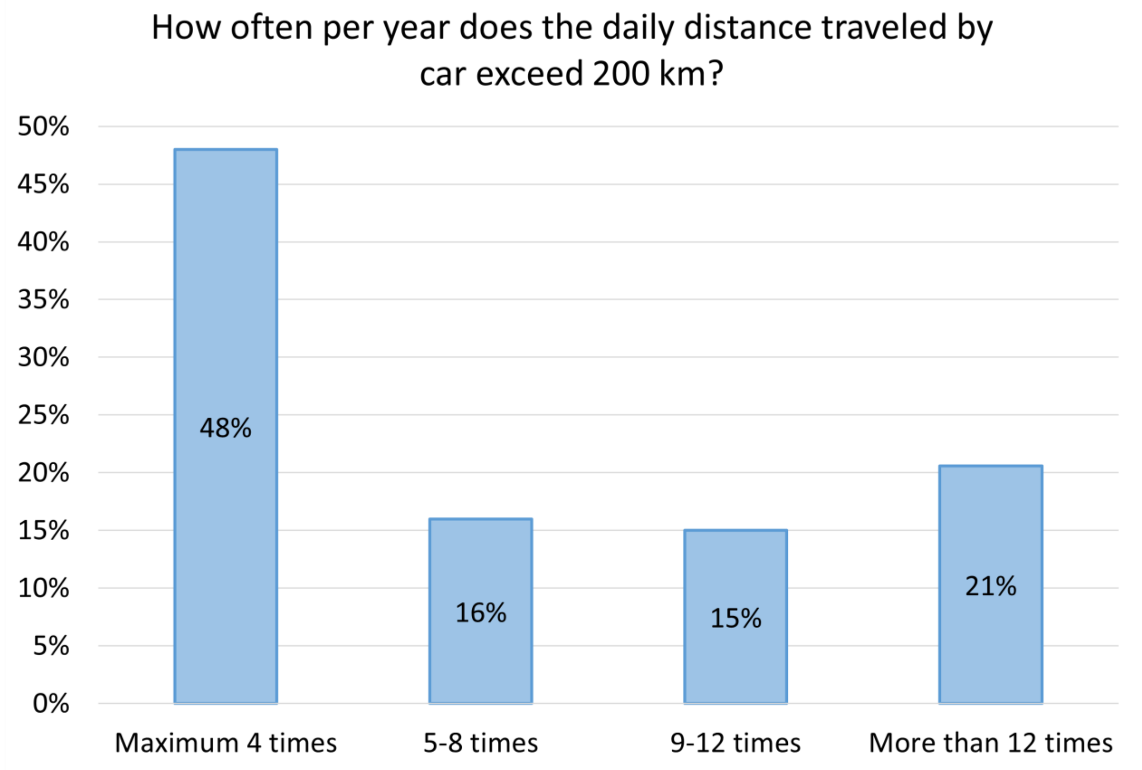
In addition to the coronavirus pandemic, supply bottlenecks are also having a severe impact on the automotive industry, which is why deliveries of new cars in 2021 were still significantly lower than before the outbreak of the pandemic in 2019.



How much have new car registrations decreased in 2021 compared to 2010? *(Correct answer -18%)*

We will now ask you the same questions again about car size and drive choice.

Please imagine the same situation again: Your most used car (main car) breaks down within this year and can no longer be repaired. In this context, we ask you again whether you would buy/lease a new car and what size/drivetrain your preferred car would have. For the decisions in the following questions, continue to assume that the charging infrastructure for electric cars, the density of car sharing stations and the options for car rental (e.g. Hertz, Avis, Europecar) are the same as today.
Information + Charging Treatment text In the next part of the study, you will have the opportunity to learn more about Swiss mobility behaviour and developments. We will provide you with information on the following question: • The actual range needs of Swiss car users and opportunity of a small electric car The discussion will be followed by a one-question quiz. Please pay close attention to the discussion so that you can correctly answer the quiz question. The effective range requirements when buying an e-car are often overestimated. Provided that the electric car can be charged overnight at home, on average more than 93 % of all daily distances in a year can be covered with an effective range of 200 km without having to charge on the road. A small electric car is already sufficient for this. In the rare cases where the daily distance exceeds 200 km, it is possible to find and reserve a charging station in the navigation device of the e-car. In addition, there is the possibility of borrowing a car for those rare cases where the range of the e-car is no longer sufficient. E.g. via carsharing or car rental.



What percentage of Swiss car users travel more than 200 km on 1 to 4 days a year? *(Correct answer 48%)*

We will now ask you the same questions again about car size and drive choice.

Please imagine the same situation again: Your most used car (main car) breaks down within this year and can no longer be repaired. In this context, we ask you again whether you would buy/lease a new car and what size/drivetrain your preferred car would have.

For the decisions in the following questions, assume that you have a charging station at home and can easily charge an e-car overnight or during the day (even if you do not have a garage space). This allows you to start every day with a full battery at home. This is marked again in the following questions with "guaranteed charging possibility at home".