Electric vehicle owner engagement with tariff switching increased by tailored email prompts sent by government shortly after vehicle purchase

Electric vehicles (EVs) are only as 'green' as the electricity used to charge them. EV charging will also challenge electricity networks. Here, we present results from a large randomised trial targeting 7,038 recipients of the UK Government's EV grant. We show that government could use administrative data from EV incentive schemes to exploit the 'window of opportunity' created when people purchase their first EV to promote energy tariff switching, including to time of use tariffs. Consistent with behavioural science, prompts emphasising reductions in home-charging costs are superior to prompts emphasising bill savings. However, governments should act soon; the 'window of opportunity' for maximising adoption is short; email open rates decline from over 70% immediately after purchase to 40% for recipients owning their EV for over three months. The results demonstrate the potential of prompts to change behaviours for which opt-out enrolment (where enrolment is automatic unless people explicitly opt-out) would be unethical or less effective.

Whilst studies have investigated methods of increasing adoption of EVs[1], the risks posed to the electricity network from charging these vehicles and, in particular, how EV owners could mitigate these risks has received less attention. This is problematic because the carbon intensity of the electricity used to charge an EV has as much to do with *when* in the day EV owners choose to charge their vehicles as it does with national fuel mixes[2]. Repetitive behaviours, such as EV charging, could become habitual and evidence to date shows that EV owners have got into the habit of charging their vehicles when they get home from work[3–5], when electricity demand is at its peak and, in many countries, the least efficient and therefore most polluting power plants are brought into operation to meet peaks in demand.[2] When charged consistently at the most polluting times, lifecycle greenhouse gas emissions from EVs can be nearly 50% higher than if charged at average electricity grid carbon intensity.[2]

As EV sales and battery capacities increase, so too do the risks to electricity networks. Estimates suggest that UK electricity networks will become overloaded when EVs reach 30%-60% market penetration[4] and that the US could charge 70% of all electric cars and light trucks, but only if charged overnight.[6] The conventional solution to such problems is to reinforce local electricity networks funded through 'green' taxes on consumer energy bills.[4] Another method is energy storage but storage technologies are still very costly[7]. A potentially cheaper alternative gaining traction amongst policymakers is to incentivise EV owners to charge their vehicles at times of low electricity demand or when renewable generation is high (demand-side response).[6,3–5,8] Smart-meters, which record energy use in near real-time, will enable the creation of new types of 'time of use' electricity tariffs which charge people less for electricity used at off-peak times (static time of use tariffs) or when renewables are more abundant (dynamic time of use tariffs). However, like other pro-environmental actions, the financial savings to the individual customer from switching to these tariffs are relatively modest[8] and mounting evidence suggests that voluntary uptake will be lower than required unless action is taken to prompt EV owners to switch.[9–11]

Here, we present results from a randomised control trial testing whether recipients of the UK Government EV grant could be prompted to consider switching tariff by sending them an email reminder shortly after purchasing their EV, when they are already likely to be thinking about the costs of running their new vehicle. The behavioural science literature[12–14] suggests that EV owners will be more susceptible to behaviour change interventions at this point in time, particularly if the email is tailored to them as EV owners.[15–20] The trial involved over 7,000 EV owners and, to our knowledge, is the largest trial run on EV owners.

The first key finding is that governments need to act soon, in the early days of the transition towards EVs; consistent with the habit discontinuity hypothesis[12–14] (that people are more susceptible to information delivered in the context of life changes), email open rates decline from over 70% to 40% for recipients who have owned their EV for over three months, equivalent to missing out on reaching an extra one million people once EVs reach 60% market penetration. The second key finding is that the framing of information is crucial; most tariff switching campaigns emphasise the energy bill savings from switching tariff however we find that EV owners are much more receptive to prompts which frame the savings as a reduction in home-charging costs, even though the monetary value of the savings presented (up to £300) were identical. The same method could also be applied in other countries with EV incentive schemes. Our results demonstrate the importance of early government intervention and that even low cost interventions such as sending a timely, tailored email to EV owners has the potential to increase enrolment rates to energy tariffs that incentivise EV owners to charge their vehicles at times of the day associated with lowest emissions.

Nudge: going beyond opt-out enrolment

Given the unpopularity of government mandates, support is growing for a policy of automatically enrolling people onto time of use tariffs, including EV owners, unless they explicitly request not to be enrolled.[21,22] Interventions which influence behaviour without using mandates, bans or significantly changing the underlying economic incentives are called ‘nudges’[23]. So-called ‘default’ or ‘opt-out’ nudges[10,11] are highly effective at increasing recruitment rates into pension schemes[24], organ donor registers[25] as well as ‘green’ energy tariffs (tariffs with a higher renewable fuel mix)[10,11]. However, critics[26] as well as proponents[27,28] of default enrolment argue that it should only be used when there is a clear, single optimal course of action that can be favoured by making it the default.[26] Unlike company pensions, the best tariff for an EV owner (whether flat-rate or time varying) will vary depending on the individual’s charging needs. Although, in principle, a personalised default rule[27] could be designed for every EV owner in the population, doing so would be challenging in practice, making it preferable, from a consumer welfare perspective, that time of use tariffs be offered to consumers on an opt-in basis. For example, a leading explanation for the effectiveness of defaults is that people are inattentive to the default option.[26] Indeed, consumers automatically enrolled on time of use tariffs reduce their peak electricity consumption by substantially less than those who actively switch[29,30], thus increasing, rather than decreasing, their energy bill. However, auto-enrolment into schemes in which a third party remotely switches off/on EV charge points to manage charging demand risks leaving consumers with half-charged cars when they need them. In the absence of default mechanisms, what can be done to encourage large numbers of EV owners to actively switch to time of use tariffs?

To answer this question, we draw on evidence from behavioural science[31] which suggests that email would be an effective mechanism by which EV owners could be prompted to switch electricity tariff. First, evidence suggests that EV owners will be more responsive to prompts delivered shortly after purchasing their EV, before they have developed strong habits over the timing of their charging[13,14,32]. This is based on the habit discontinuity hypothesis which predicts that people are more susceptible to behaviour change campaigns shortly after they have engaged in other life changes, such as moving home.[12–14,32] The assumption is that, “when habits are (temporarily)

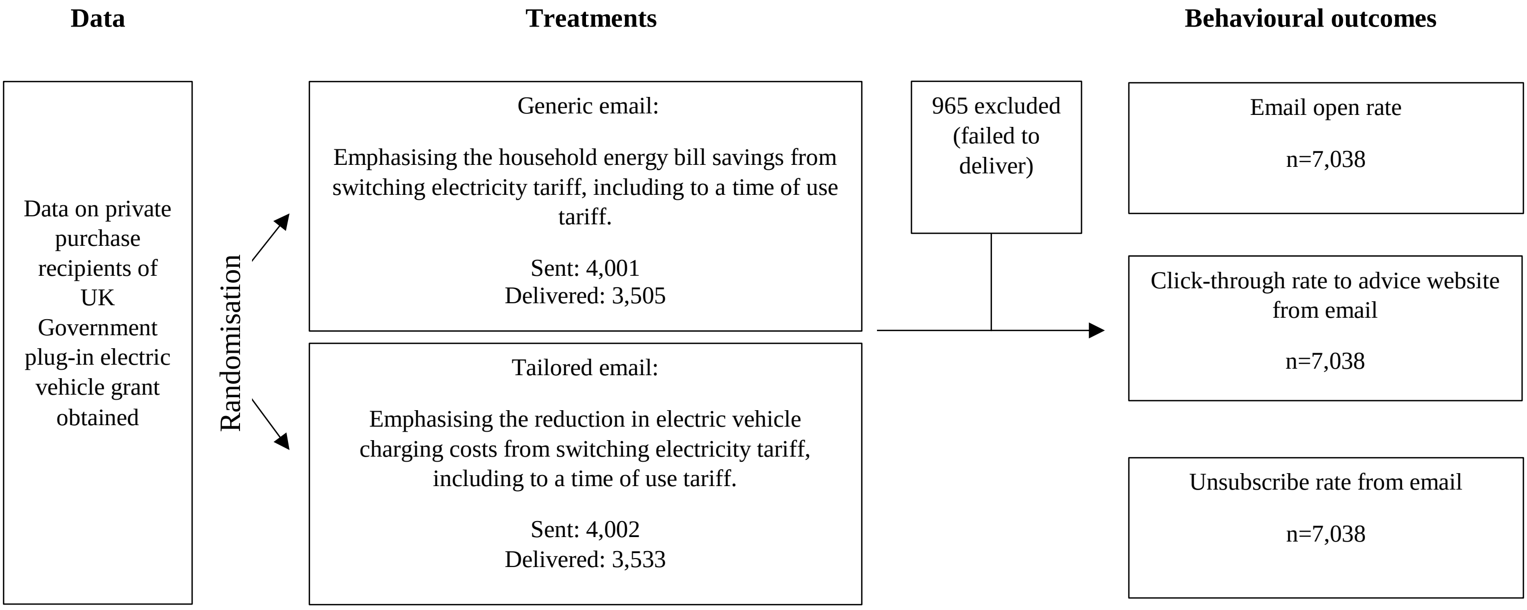

Figure 1 | Experimental procedure. Diagram showing the process by which data on electric vehicle owners were obtained, through to randomisation to assignments and collection of outcomes.

disturbed, people are more sensitive to new information and adopt a mind-set that is conducive to behaviour change”[13] [(p.1)]. Although buying a new car may not be as significant a life transition as moving home, purchasing an EV incurs significant financial costs and requires non-trivial changes in usage relative to traditional internal combustion engine vehicles.

Second, although information-based appeals are easy to ignore, contrary to rational-choice theories, people are much less likely to disregard information that is tailored[20] to them, suggesting that an EV-specific tariff switching campaign would be more effective than a generic broadcast campaign. This is based on the assumption that tailoring, the process of “enhancing the relevance and salience of information”[18, p.187] increases motivation to process information, making behaviour change more likely.

Study design and participant recruitment

To test these hypotheses, we carried out a large randomised control trial (n=7038) with the UK Government Office for Low Emission Vehicles (OLEV), the department responsible for administrating the Plug-In Car Grant (PICG). The PICG automatically deducts up to £5,000 from the sale price of eligible EVs. The data associated with these grants contains the email address and date of purchase of nearly all EV owners in the UK. Since the grant is automatically awarded to recipients at the point of sale and over 95% of EVs bought in the UK are grant-eligible models[33], our dataset encompasses nearly all private purchase EV owners in the UK and approximately 10% of total UK EV owners (the remainder are fleet EVs and EVs purchased by leasing companies – see Methods for more details).

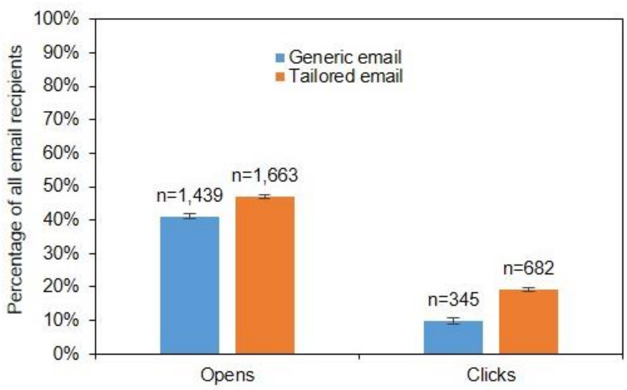

Figure 2 | Proportion of email recipients opening email and clicking-through to online advice page by experimental condition. Error bars represent standard errors, calculated by dividing the standard deviation by the square root of the sample size. The bar labels represent the sample size opening or clicking through in each group.

As illustrated in Fig. 1 recipients of the grant were randomly assigned to receive one of two emails prompting them to switch electricity tariff. The benefits of switching were framed in terms of either: (1) saving £300 on their household energy bills (generic email); or (2) reducing the cost of charging their EV by £300 (tailored email). Both emails were sent from a UK Government for Low Emissions Vehicles email address and encouraged recipients to visit a webpage containing tips on how to cut the cost of their household energy bills (generic email) or cut the cost of home charging (tailored email) – see Supplementary Table 1 for details.

The email and tips included a time of use tariff which has a cheaper rate overnight, when electricity demand is lowest and renewable generation (i.e. wind) is highest. Balance checks on baseline characteristics reveal that the randomisation was successful (see Supplementary Table 2 for the results of these tests).Following best practice from medical trials, all analyses except three were specified in advance within a pre-analysis plan (egap trial registration number 20160726AA) to avoid concerns about arbitrary ‘specification searching’ – see Supplementary Methods for details.

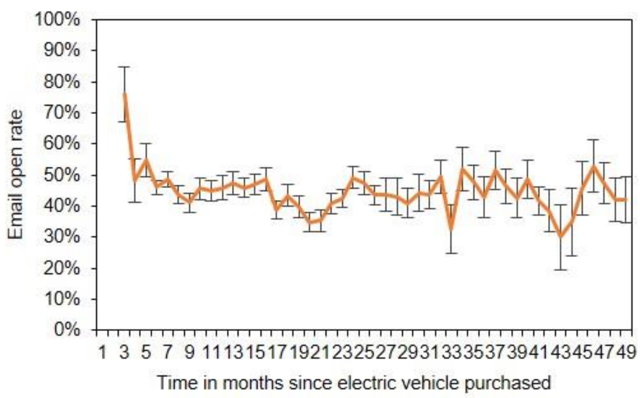

Figure 3 | Proportion of email recipients opening email by the time in months since the recipient purchased their electric vehicle. Error bars represent standard errors, calculated by dividing the standard deviation by the square root of the sample size. Outliers removed (see Supplementary Information).

Table 1 | Explaining email open rates by time since EV purchased

	(1)	(2)	(3)	(4)	(5)
Time since vehicle purchased in months	-0.004*				
(p value)	(0.027)				
Log of time since purchase in months		-0.105**			
(p value)		(0.005)			
Quartiles of time since purchase in months			-0.048*		
(p value)			(0.028)		
Purchased vehicle three months ago				1.395**	1.228**
(p value)				(0.003)	(0.010)
Individual and vehicle control variables					√
Observations	7038	7038	7038	7038	2891
Pseudo R^2 (McFadden's)	0.001	0.001	0.001	0.001	0.014
Nagelkerke R^2	0.001	0.001	0.001	0.002	0.025

Throughout all models, the dependent variable is a dummy variable indicating whether the recipient opened the email. Model 1 reports results of a pre-specified logit regression in which the independent variable is time in months since the recipient purchased their EV from the date of the email being sent, with no controls. Model 2 reports the results of a logit regression in which the independent variable is the log transformation of time in months since the recipient purchased their EV, with no control variables. Model 3 reports results of a pre-specified logit regression in which the independent variable, time in months since purchasing the vehicle, has been split into quartiles. Model 4 reports the results of a logit regression in which the independent variable is a dummy variable which takes on the value one if the recipient received their EV three months ago and zero if the recipient received their EV four months or more ago, with no control variables. Model 5 reports the results of a robustness check using the same specification as Model 4 but which includes a series of control variables collected at the time of purchase: vehicle price, vehicle type, gender, age, employment status, number of vehicles in the household, whether the EV will be the main vehicle and expected annual mileage. The sample size in Model 5 is smaller because there are missing observations for the covariates, however a further robustness check which includes only controls for missing variables provides similar results. All regressions were estimated with robust standard errors. Traditional p-values reported in brackets (however the p-values on both dummy specifications withstand corrections to account for multiple hypothesis testing using the Benjamini and Hochberg[35] method).

* p<0.05, **p<0.01, ***p<0.001.

Email open rates and tailored messaging effects

Email open and click-through rates were high, with over 40% of recipients (n=3,102) opening the email, compared to an industry average for email communication of just 22%[34], and 15% clicking-through (n=1,027) to the advice webpage (industry average >3%)[34]. Moreover, as shown in Fig. 2. and as predicted, open rates were 15% higher ($p<0.001$) and click-through rates 90% higher ($p<0.001$) amongst participants who were prompted to switch to cut the costs of charging their EV by £300 (tailored email) rather than cutting the cost of their energy bill by £300 (generic email).

Although recipients could unsubscribe from future emails by clicking a link at the bottom of the email, very few did so (n=59); significantly fewer unsubscribed in the tailored email relative to the generic email ($p<0.05$). Over 1,000 users downloaded the guides on the Energy Saving Trust website in the first week, equivalent to one download for every three people who opened the email. Although it was not possible to link the interventions to the downloads, it seems likely that a higher proportion will have been made by those in the tailored condition because 90% more people visited the webpage in this condition than the generic email condition; however, the data do not allow us to confirm this hypothesis.

Testing the habit discontinuity effect

Some participants had purchased their EV as recently as three months prior to receiving the email whereas others had owned their vehicle for over five years. In line with our pre-analysis plan, regression analysis was used to test whether willingness to consider switching tariff declines the longer ago the recipient purchased their EV (the habit discontinuity effect), in which time in months since purchasing the EV is regressed against the email open rate (binary 1=yes; 0=no).

Consistent with the habit discontinuity hypothesis, the regression revealed a small but statistically significant negative coefficient, implying that email open rates slightly decrease as time since purchasing an EV increases ($c=-0.004$, $p<0.05$) including in a further robustness check using the log transformation of time since purchase in months to account for the rightwards skew in EV sales ($c=-0.105$, $p<0.01$). See Table 1 for the full regression output from this analysis.

However, as predicted, visual inspection of the data (Fig. 3) reveals a marked non-linearity in this relationship, suggesting that, consistent with prior studies[13,14], there is a discrete 'window of opportunity' for influencing behaviour; email open rates decline from over 70% to 40% between those who had purchased their EV three months ago (the most recent group of EV owners in the dataset) and those who had purchased their EV four months ago or more (Fig. 3). Consistent with our pre-analysis plan, we split the sample into quartiles based on the time in months since purchase and regressed this against open rates, to also find a statistically significant negative coefficient ($c=-0.048$, $p<0.05$), in support of the habit discontinuity effect.

To test whether the sharp decrease in open rates between the third and fourth month since purchase is statistically significant – i.e. whether this represents a genuine 'window of opportunity' for encouraging EV owners to switch tariff – an additional logit regression was run in which the independent variable is a dummy indicating whether the recipient received their EV three months since the email was sent (1) or more than three months since it was sent (0). As predicted, receiving a prompt within three months of owning an EV ($n=30$) has a strong and highly statistically significant positive effect on the likelihood of opening the email ($c=1.395$, $p<0.01$), including in a further robustness check which includes a battery of control variables collected at the time of purchase: vehicle price, vehicle type, gender, age, employment status, number of vehicles in the household, whether the EV will be the main vehicle and expected annual mileage ($c=1.228$, $p<0.01$). The p-values on both these dummy variables are robust to multiple hypothesis corrections using the Benjamini and Hochberg[35] procedure.

Conclusions

In summary, we demonstrate that policymakers could exploit the 'window of opportunity' created when people purchase their first EV to prompt an entire and growing sub-group of the population to participate in demand-side response (using electricity when generation is cleaner and cheaper but overall demand lower). To our knowledge, this is the largest and only population-wide study on EV owners and the only study to test a method of encouraging EV owners to switch electricity tariff. By using theory to pre-specify our data analysis and visualisation of the raw data to supplement our pre-specified analysis, we minimise the risk that we are only seeing an effect in one particular cut of the data, that would not be present if we cut or analysed the data in a different way, a practice which notoriously undermines the replicability of research findings[36].

The findings add weight to psychological rather than rational choice theories of individual decision-making and are therefore of relevance to the broader literature on climate change communication and pro-environmental behaviour. For example, it is often assumed that if consumers do not invest in energy efficient appliances or switch electricity tariff it is because they are unaware of the benefits or because the costs of switching or green investment are too high.[37,38] This model of consumer decision making is based on the assumption that consumers are rational. However, the fact that so many more EV owners opened the email prompting them to switch tariff when framed in terms of the potential £300 reduction in their home charging costs rather than a £300 reduction in their household energy bills – and when the email was sent within 3 months of purchase – adds to the increasing evidence[23] that the model of the utility maximising agent from classical economics is a poor approximation of how people actually make decisions.

Two potential mechanisms are most likely to account for the impact of tailoring. The first is inattention to insalient costs, or myopia as proposed in Gabaix and Laibson's[39] model. According to this model, "add on" costs are less salient than purchase costs and consumers do not rationally gather information about 'shrouded' costs. As argued elsewhere[40], fuel costs (e.g. the cost of charging an EV) are analogous to "add on" costs in that, unlike the purchase price, they are not explicitly presented upfront. Many new EV owners may therefore not perceive themselves as having higher than average electricity consumption and, unlike the generic email, the tailored email 'unshrouds'[39] the insalient costs of owning an EV, thereby encouraging EV owners to act to lower these costs. A second related mechanism proposed in the literature on tailored health communication[18] is that tailoring increases the perceived relevance and salience of information, thereby increasing motivation to process and act on it, in this study, by visiting information about how to reduce the costs of charging an EV.

Although our study was unable, for practical reasons, to track whether EV owners went on to switch tariff as a result of the prompts, theory[41] and empirical evidence[42] suggest that the intermediate outcomes measured (open rates, click-through rates, downloads) will be correlated with switching; even if just 5 percent of those who open the email switch tariff, that could mean an additional 135,000 EV owners switching tariff once EVs reach 60% market penetration, at almost zero cost. If these email prompts focused on promoting time of use tariffs, and EV owners switched from flat-rate to time of use tariffs, early evidence suggests that such tariffs could reduce peak time charging by 50%[3].

However, unlike default enrolment (the most common 'nudge'[23]), prompts do not succeed by encouraging choice without awareness[43] and therefore increase the likelihood of active rather than passive participation in demand-side response, whereby people defaulted onto time of use tariffs do not substantially alter their energy consumption patterns.[22,30]

Although this study was run on recipients of the UK Government's EV grant, a number of countries (e.g. India, China, South Korea, Sweden, Germany, Netherlands, Portugal) run similar EV subsidy schemes for which contact data is also likely to be collected to enable the sending of timely, tailored email prompts. Moreover, the same approach could also be tested in the context of other new low carbon technologies such as the installation of new electric heating systems, which are also expected to place a great strain on the future electricity network[44] but which are also subject to similar government incentive schemes. A key contribution of this study is to demonstrate how additional value can be obtained from this administrative data.

Finally, this study demonstrates for the first time that the habit discontinuity effect applies beyond life changing events such as moving house. Based on our results, we estimate that sending an email prompt in the first three months of purchasing an EV could mean reaching an additional one million EV owners compared to sending the email at a later time once 60% of the population has an EV. We echo the calls of other researchers for the greater application of behavioural science to the design of interventions aimed at fostering positive energy consumption behaviours.[45,46]

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