Assisting EV Drivers to Act Smarter:

How behavioral tools can facilitate adoption of smart navigation and greenify mobility

Kacperski, Celina & Kutzner, Florian
Department of Consumer Psychology
University of Mannheim
Mannheim, Germany
kacperski@uni-mannheim.de, kutzner@uni-mannheim.de

Abstract— **The aim of the ELECTRIFIC project is to integrate electromobility into the grid in a smart way, by guarding grid stability while optimizing the share of renewable energy in EV batteries. A purely technical solution for grid integration can be implemented, but is easily rendered obsolete in cases where optimal charging and routing solutions are suggested but not chosen by the driver. The main idea presented in this paper is the use of behavioral science to incentivize users to align their behavior with the ELECTRIFIC technical solution. We view this as an opportunity: by employing insights from latest research into symbolic incentives and gamification, EV drivers, empowered by intelligent systems, can make the choice to promote a stable grid, long battery life and a high share of renewables.**

Keywords - behavioural science, gamification, nudges, incentives, smart solutions

I. Introduction

Electromobility is often seen as one way to drastically reduce the impact of our mobility needs on the environment [1], [2], but the adoption of electric vehicles (EVs) as a wide-spread measure still holds many challenges. Before EVs become the standard, an environmental perspective demands that we guarantee a stable grid, prolong battery life such that the impact of recycling is minimal, and supply the highest possible share of renewables. One solution is to provide a technology that predicts the grid load, calculates energy efficient routes and suggests environmentally friendly charging. The main goal of the ELECTRIFIC project is to create a prototype of such a technical solution, in the form of smart navigation that suggests the user a *green route* as an alternative to the ubiquitous *fastest route*.

Adoption of smart technologies, e.g. smart home, medical and grid technologies, is a topical debate [3]–[6]: without the willingness of users to integrate smart solutions into their lives, it will not be possible to solve many contemporary issues, including those created by increasing demand for EV mobility. Ultimately, it is the EV drivers who decide when and where to drive and to charge.

One way to incentivize users to adhere to proposed charging and driving patterns is via financial incentives. However, price-sensitivity of users has not been found to be as high as expected, and research on financial incentives shows they are costly to uphold in the long-term and if removed, might show a reverse reaction to what is desired [7]–[9]. Behavioral steering techniques can be adopted as a more suitable alternative, and might turn out to play a larger role when engaging with smart solutions in the future.

II. Theoretical Background

Integrating smart technologies is easiest when they fit in with their surroundings, follow conventions, are based on people's previous knowledge [10], and when they can evolve with people's preferences [11]. Otherwise they will just be perceived as an additional source of stress and complexity. An understanding of the added value that a technology brings and high usability are also top priorities [12], [13]. For smart navigation, this means that aside from providing people a green solution, this choice needs to be tailored to their lifestyle and evolve with their habits and schedules. Additionally, the workings of the grid and charging structures are poorly understood by the public [4]: thus, adherence to suggestions might be hampered by a lack of information.

Some of these barriers can be overcome with methods developed based on psychological insights. Sometimes it is as simple as designing a GUI with the correct default setting, a means that can be upheld for long periods of time without additional costs. A default, i.e. the option that is preselected when making a choice, has been shown to work very well: people do not often switch to the alternatives [14]. For example, in countries that have an opt-out system for organ donations in place (as opposed to an opt-in system where one has to actively sign up to become an organ donor), the majority of the population are registered organ donors and only a small percentage of people opt out actively [15].

The mechanism is such that by improving the way information is presented or framed, we can provide users with structure in complex situations and support them in their decision-making. As another example, social norms give information about what many other individuals in the same situation have done before [16], [17]. When given information about their neighborhood energy consumption, household electricity usage could so be reduced; individuals learned that the majority of their neighbors had lower energy consumption and chose to align their usage [18].

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Lack of understanding can be counteracted by providing additional information to consumers. In particular, framing information in a more meaningful or evaluable manner can account for additional insights and increase adherence [19]–[21], for example by providing a measure of CO2 in terms of trees planted or polar bears saved [22].

Finally, the use of games or game elements to increase certain behaviors (such as the phenomenon of Pokémon Go for walking [23]) has become popular in recent years, termed gamification [24]. Due to the current abundance of interactive systems, it is possible to employ a variety of game mechanics such as point systems, badges and leadership boards, avatars and even storytelling and social interaction, which have been shown to induce positive behaviors in education, marketing and sustainability [24]–[26]. For example, a smart meter for electricity use was more effective when household members had to keep their avatars alive via an energy point collection system [27]. In another instance, point collection and levels increased performance in a software learning setting [28]. Receiving collectables (such as green points) for route and/or charging adherence, and an integration of avatars, could then increase the impact and effectiveness of ELECTRIFIC.

III. Methodology

The ELECTRIFIC solution consists in part of the ADAS: an advanced driver's assistant system, which will give the user the opportunity to choose between a fastest route, and a green route. Ultimately, green routes should be calculated based on grid stability and congestion, energy efficient routing and renewables currently available, and include real time information on traffic and the possibility of charging station reservation ahead of time. The final solution will involve whole-day scheduling: users will be able to input recurring events, and upload their schedules and appointments and the system will also learn common destinations based on past behavior. The ADAS will then plan the whole day, optimizing based on the users' demands and maximization of green metrics. In a first prototype, we will include a greenest route optimization and charging suggestions, but for single trips with one destination only.

We plan to conduct multiple experimental field trials (randomized controlled trials) during the project, involving interventions and control groups, so that we can make accurate predictions about the effectiveness of the previously described behavioral steering techniques in an applied electromobility setting.

A. Default Trial

Our first trial will investigate the effect of defaults. We expect that users of the ADAS will stay with the default route that is pre-selected. Thus, when the default is the green route, more drivers will use it to navigate, as compared to an active choice control group, or a fast route default. See Fig. 1 for an illustration of a possible implementation of this architecture.

Participants will be recruited in Bavaria, Germany, primarily through EV car sharing services but also through newsletters, internet fora and email lists of charging station operators. EV drivers will receive an invitation to participate in a trial to test the first iteration prototype of the ADAS and instructions how to download the app to their smartphones. Participants will be explained the purpose and methodology of the trial and explained their right to leave the trial and have their data removed at any time. They will receive 5 Euro vouchers for using the ADAS for at least one trip.

As dependent variables, we will log in-app choices, as well as route and charging adherence. We predict that the green route default will increase the green choice, and increase the number of users who follow this route and charge at their destination, if a charging suggestion has been made. Routing adherence will be operationalized by GPS log, and charging adherence by GPS location and data from charging station operators. Investigating one factor (default) on three levels (green, fast, active choice), we estimate that will require 300 participants - 100 per group - for sufficient statistical power.

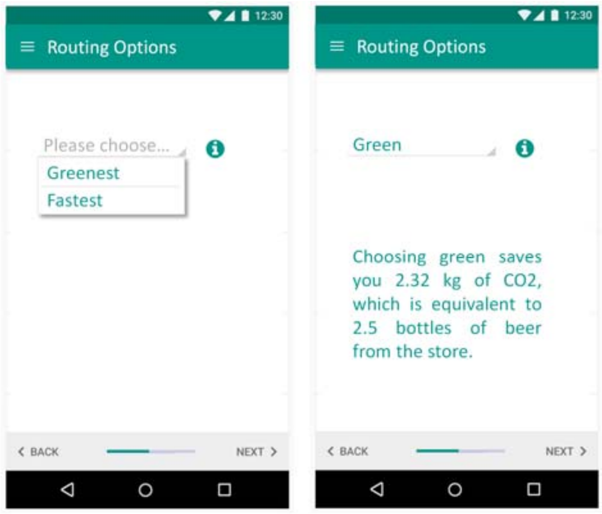

Figure 1. Examples of ADAS GUI. Left-hand image shows active choice default preset, where users can choose greenest or fastest route. Right-hand image shows green route default. Additionally, users can be presented with incentive text below their routing choice.

We will additionally ask participants for their state of charge at the start and end of their trip to have an approximation of the energy-efficiency of their driving style, and fill in a short questionnaire about their satisfaction with their trip to gauge changes in levels of EV attractiveness. Finally, we will match their ADAS use with user profiling done through an online survey where we ask about their mobility behavior and attitudes towards electric mobility and the environment. Participants will receive the online survey via the email that they can provide inside the application.

B. Incentives Trial

The incentives trial will run parallel to the Default Trial, and additionally test the effect of text-based, symbolic incentives, such as evaluability information and social norms. We will test the strength of these interventions against the effects of material incentives such as coupons and a control group without incentive. An example of evaluability information can be found in Fig. 1, where we inform the driver that their CO2 savings from a trip using the green route consist of 2.32kg, the equivalent of the CO2 expenditure to produce 2.5 bottles of beer. On all other counts, the same methodology as in the Default Trial will be employed.

C. Gamification Trial

We will commence with this trial when a mature version of the ADAS prototype is available, which will enable whole-day scheduling and long-term engagement with the application. We will devise metrics that will correspond to green or fast route to generate a point system by which the user will be able to collect points and earn badges and rewards. Energy-efficient driving, green routing and grid-friendly charging will be rewarded with green points, which the user will collect at the end of every trip.

We will compare a simple point system, in which the points are translated into informational badges, against a point system which translates to material incentives. Thus, some users will encounter a starting screen in which their points represent, for example, the badge "EV for 100 trees" when they have saved CO2 equivalent to what 100 trees pull from the air in a day, and some users will encounter a starting screen that tells them that "reach 1000 green points, receive a cinema ticket". Additionally, half the users will be able to choose an avatar when they are setting up an account. The other half will use the ADAS without an avatar representation.

Participants will once again be recruited like in the previously described trials. Due to anticipated interest in such an application, we will not be offering any payment for this trial. We are investigating two factors (points, avatars) on two levels each (informative/material and avatar present/absent), and need one control group, therefore, we will recruit around 500 participants in this trial. Again, we will collect information on route selection, driving and charging adherence through GPS and charging station information. Additionally, we will implement acceleration and positioning logging to better track driving behavior to explore any interaction between interventions and style of driving. We will also ask participants to fill in a short questionnaire about their satisfaction with the service at the end of each use, and match their navigation use with user profiling done through an online survey as described before.

IV. DISCUSSION

Understanding how EV users can be guided towards sustainable behavior is a main goal of ELECTRIFIC. For mobility behavior, this means optimal use of the grid infrastructure through smart routing and charging, particularly with an eye on maximizing renewable intake and battery-friendly driving styles. Beyond the environmental perspective, adherence to smart navigation can also increase cost-efficiency for stakeholders: not just the drivers, but also charging station providers, whose net profit can be maximized through the use of renewable energy that is sourced locally such as solar panels, and, of course, grid operators, whose main interest is keeping power quality high.

One main issue through which EVs impact local power quality is a psychological phenomenon called "range-anxiety" – the fear that one will not be able to reach one's destination (the next charging station) due to perceived unpredictable electricity depletion of the battery [29], [30]. As a result of range anxiety, charging today happens in an erratic, uncoordinated manner outside the home. As an alternative issue, drivers who own vehicles that they use to almost exclusively to go to work will generally plug their vehicles in at the same time, when they come home in the early evening. These patterns of charging are projected to lead to substantial increases of the system peak load for 2020 and 2030 projection scenarios [31].

If by 2050, combustion engine vehicles can be eliminated and replaced by electric alternatives [32], it will be in the interest of grid operators to influence drivers' charging behavior, for example by addressing range anxiety issues, and controlling charging patterns in general. A smart navigation solution that automatically coordinates charging along EV drivers' daily schedule will be the first step, and incentivizing them to adhere to the ADAS suggestions will allow users to stay powered while staying green at the same time.

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REFERENCES

[1] European Commission, "Clean and energy efficient vehicles: European Commission tables strategy," Brussels, 2010.

[2] F. Leurent and E. Windisch, "Triggering the development of electric mobility: a review of public policies," Eur. Transp. Res. Rev., vol. 3, no. 4, pp. 221–235, Dec. 2011.

[3] N. Balta-Ozkan, R. Davidson, M. Bicket, and L. Whitmarsh, "Social barriers to the adoption of smart homes," Energy Policy, vol. 63, pp. 363–374, Dec. 2013.

[4] R. Chang, Y. Yuan, H. Lv, W. Yin, and S. X. Yang, "Selling the Smart Grid Part 1: Why Consumers Must Buy In for the Smart Grid to Succeed," IEEE Consum. Electron. Mag., vol. 1, no. 2, pp. 24–31, Apr. 2012.

[5] D. J. Cook, "How Smart Is Your Home?," Science, vol. 335, no. 6076, pp. 1579–1581, Mar. 2012.

[6] C. Wilson, T. Hargreaves, and R. Hauxwell-Baldwin, "Smart homes and their users: a systematic analysis and key challenges," Pers. Ubiquitous Comput., vol. 19, no. 2, pp. 463–476, Feb. 2015.

[7] U. Gneezy, S. Meier, and P. Rey-Biel, "When and why incentives (don't) work to modify behavior," J. Econ. Perspect., vol. 25, no. 4, pp. 191–209, 2011.

[8] U. Gneezy and P. Rey-Biel, "On the Relative Efficiency of Performance Pay and Noncontingent Incentives," J. Eur. Econ. Assoc., vol. 12, no. 1, pp. 62–72, Feb. 2014.

[9] M. Promberger and T. M. Marteau, "When do financial incentives reduce intrinsic motivation? Comparing behaviors studied in psychological and economic literatures.," Health Psychol., vol. 32, no. 9, pp. 950–957, 2013.

[10] M. Stringer, G. Fitzpatrick, and E. Harris, "Lessons for the future: experiences with the installation and use of today's domestic sensors and technologies," in Pervasive, 2006, pp. 383–399.

[11] W. Edwards and R. Grinter, "At home with ubiquitous computing: Seven challenges," in Ubicomp 2001: Ubiquitous Computing, 2001, pp. 256–272.

[12] K. Walsh and A. Callan, "Perceptions, Preferences, and Acceptance of Information and Communication Technologies in Older-Adult Community Care Settings in Ireland: A Case-Study and Ranked-Care Program Analysis," Ageing Int., vol. 36, no. 1, pp. 102–122, Mar. 2011.

[13] M. D. Rodríguez, V. M. Gonzalez, J. Favela, and P. C. Santana, "Home-based communication system for older adults and their remote family," Comput. Hum. Behav., vol. 25, no. 3, pp. 609–618, May 2009.

[14] D. Pichert and K. V. Katsikopoulos, "Green defaults: Information presentation and pro-environmental behaviour," J. Environ. Psychol., vol. 28, no. 1, pp. 63–73, Mar. 2008.

[15] E. J. Johnson, “MEDICINE: Do Defaults Save Lives?,” Science, vol. 302, no. 5649, pp. 1338–1339, Nov. 2003.

[16] R. B. Cialdini, R. R. Reno, and C. A. Kallgren, “A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places,” J. Pers. Soc. Psychol., vol. 58, no. 6, pp. 1015–1026, 1990.

[17] N. J. Goldstein, R. B. Cialdini, and V. Griskevicius, “A Room with a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels,” J. Consum. Res., vol. 35, no. 3, pp. 472–482, Oct. 2008.

[18] P. W. Schultz, J. M. Nolan, R. B. Cialdini, N. J. Goldstein, and V. Griskevicius, “The Constructive, Destructive, and Reconstructive Power of Social Norms,” Psychol. Sci., vol. 18, no. 5, pp. 429–434, May 2007.

[19] K. Stenning and J. Oberlander, “A Cognitive Theory of Graphical and Linguistic Reasoning: Logic and Implementation,” Cogn. Sci., vol. 19, no. 1, pp. 97–140, Jan. 1995.

[20] I. P. Levin, S. K. Schnittjer, and S. L. Thee, “Information framing effects in social and personal decisions,” J. Exp. Soc. Psychol., vol. 24, no. 6, pp. 520–529, Nov. 1988.

[21] A. M. O’Connor, “Effects of framing and level of probability on patients’ preferences for cancer chemotherapy,” J. Clin. Epidemiol., vol. 42, no. 2, pp. 119–126, 1989.

[22] W. Brazil, B. Caulfield, and N. Rieser-Schüssler, “Understanding carbon: Making emissions information relevant,” Transp. Res. Part Transp. Environ., vol. 19, pp. 28–33, Mar. 2013.

[23] A. G. LeBlanc and J.-P. Chaput, “Pokémon Go: A game changer for the physical inactivity crisis?,” Prev. Med., vol. 101, pp. 235–237, Aug. 2017.

[24] K. Seaborn and D. I. Fels, “Gamification in theory and action: A survey,” Int. J. Hum.-Comput. Stud., vol. 74, pp. 14–31, Feb. 2015.

[25] J. Hamari, J. Koivisto, and H. Sarsa, “Does Gamification Work? -- A Literature Review of Empirical Studies on Gamification,” 2014, pp. 3025–3034.

[26] M. D. Hanus and J. Fox, “Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance,” Comput. Educ., vol. 80, pp. 152–161, Jan. 2015.

[27] Y. Liu, T. Alexandrova, and T. Nakajima, “Gamifying Intelligent Environments,” in Proceedings of the 2011 International ACM Workshop on Ubiquitous Meta User Interfaces, New York, NY, USA, 2011, pp. 7–12.

[28] W. Li, T. Grossman, and G. Fitzmaurice, “GamiCAD: A Gamified Tutorial System for First Time Autocad Users,” in Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology, New York, NY, USA, 2012, pp. 103–112.

[29] O. Egbue and S. Long, “Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions,” Energy Policy, vol. 48, pp. 717–729, Sep. 2012.

[30] T. Franke, I. Neumann, F. Bühler, P. Cocron, and J. F. Krems, “Experiencing Range in an Electric Vehicle: Understanding Psychological Barriers,” Appl. Psychol., vol. 61, no. 3, pp. 368–391, Jul. 2012.

[31] W.-P. Schill and C. Gerbaulet, “Power system impacts of electric vehicles in Germany: Charging with coal or renewables?,” Appl. Energy, vol. 156, pp. 185–196, 2015.

[32] European Commission, “Transport 2050: Commission outlines ambitious plan to increase mobility and reduce emissions,” Brussels, 2011.