A Behavioral Perspective on Smarter EV Use

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

Wautelet, Jérémy
Digital Business Unit
Gfi
Leuven, Belgium
jeremy.wautelet@gfi.be

***Abstract*—The present paper offers an effective approach to integration of behavioral science insights into a navigation recommender system software. The goal is to provide EV drivers with an intelligent navigation system that allows the choice between different routing recommendations. We investigate which incentives are most successful at encouraging users to make decisions that promote a stable grid and the use of renewable energies. We present the current and planned user interface of the ELECTRIFIC ADAS - an advanced driver assistance system developed within the framework of the Horizon 2020 project "ELECTRIFIC" and a selection of behavioral steering techniques - such as financial and symbolic incentives, or default settings – that will be employed within the context of the ADAS system.**

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

I. Introduction & Theoretical Background

Solutions to grid stability issues are rarely discussed at the level of EV user behavior, even as it is known that these issues will stem from a large-scale adoption of EVs in our everyday lives [1], [2] – and that the behavior of users will be a major factor in how well EVs are integrated. Technological solutions such as smart navigation, smart chargers and charging schedulers are important components of tackling future grid instabilities [3]–[5]; however, one of the major obstacles that these technologies face is whether individuals are willing to adopt them, and adhere to their recommendations.

The ecological impact of mobility systems on the environment is currently also of strong political and economic interest [6], [7]. EVs are understood as a major opportunity to reach CO_2 goals via a reduction in fossil fuel use and increase of the use of renewable energies. Again, impacting users' charging and driving behavior can be one path to optimizing the intake of renewables into the battery, while at the same time improving battery health and longevity [8]–[11]; and again, willingness to adopt technological solutions and adhere to their recommendations is crucial for success.

In areas such as home technology, medicine and grid regulation, smart solutions are becoming more and more widely used, with much research dedicated to their usability and effectiveness [12]–[16]. First evidence suggests that adoption occurs in instances when the smart technology is well integrated in users' everyday lives and surroundings, in a way that is familiar and based on previous experiences with similar technology; it is hindered by interaction complexity, too much necessity for pre-planning, and a lack of understanding of the added value that a technology brings [17]–[20]. For example, rollouts of smart meters in the UK have been met with controversy despite objective benefits in the form of energy savings, and supposed ease of use of these meters. Analyses of this failure of adoption have found that main drivers were a lack of careful user engagement, lack of informational materials and lack of attention to privacy and security concerns of the end users [21].

As demand and use of EVs increase, GPS and car system manufacturers are in the process of developing solutions for smart navigation and smart charging of EVs in particular, with prominent examples of navigation systems specialized for EVs by Tomtom, Sygic and Pioneer; the common goal in all these is optimization of battery use (for example via integration of an eco-mode) and route planning based on driving style and vehicle characteristics. At the same time, it will be important to provide users with relevant real time information about charging stations (CS) and parking.

The mentioned systems will certainly aim to provide a seamless charging experience and fast trip completion. However, the scope of the ELECTRIFIC project is to additionally motivate users to charge in a grid friendly manner and to maximize renewables [5], [16]. To reach this goal, more information needs to be integrated; real-time feedback on the grid status as well as availability of renewables need to be provided in order to suggest the best charging station (CS) available to the user not only in terms of speed of use, but also in terms of a greenness parameter.

An important hint to more effective implementation of smart solutions into an already existing mobility system can be found within the investigation into the failure of the Better Place system, which was funded to increase EV adoption and reduce range anxiety in two target markets in Denmark and Israel. Better Place provided a comprehensive charging infrastructure to reduce range anxiety and battery swapping as a way to decrease charging times [22]; however, as it turned out, this did not lead to successful implementation. In the end, Better Place lacked insight into

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reasons why drivers were unwilling to change their behaviors, identities and habits, as well resourceful incentives targeting these reasons. Since ultimately, it will be EV drivers who decide when and where to drive and to charge, a high level of usability and the implementation of persuasive incentive structures into the design are mandatory for building valuable smart tech or software solutions that are also green and grid friendly.

II. BEHAVIOR STEERING TECHNIQUES

Adherence to smart navigation recommendations can be hindered by two main factors, namely a lack of motivation to follow the suggestion and/or a lack of the knowledge necessary to make informed decisions. In behavioral science, multiple methods have been developed to help overcome such barriers; one possible way to do so is via the employment of choice architecture [23]. The term choice architecture was coined to endorse a psychologically thoughtful design of interfaces or environments; often, this involves targeting biases and heuristics which individuals use to accelerate the decision-making process [24], often leading to decision errors. One example of such a bias is the sunk cost fallacy [25], in which a dessert is eaten entirely because one has already paid for it, even when one is no longer enjoying it halfway through, in effect paying for it twice.

Elements of choice architecture that are implemented in the ELECTRIFIC ADAS are the reduction of choice overload; setting of defaults; and integration of evaluative feedback. Financial incentives – i.e. rewards or punishments in monetary form, such as a reduction of participant compensation, are employed concurrently to test the effects of choice architecture against the efficiency of financial steering techniques in an experimental fashion. The execution of these elements will be described in detail in the results section.

There are advantages of choice architectural elements over traditional, usually material forms of incentives. For one, they can be upheld over long periods of time without incurring additional costs. For another, the approach is such that users are only nudged in a certain direction, without in reality limiting their choices and without any direct negative consequences for not choosing the nudged option [23].

Reducing choice overload is at the core of the ELECTRIFIC ADAS; evidence suggests that with too many choices at their disposal, users show less motivation to make good choices, and are less satisfied with their chosen option later on [26]. In a future EV mobility scenario where many charging options are available, it will therefore be beneficial for users to have optimization criteria that help preselect their mobility behavior based on for example fastest, greenest and cheapest routing and charging. ELECTRIFIC ADAS suggests a CS in a radius around the input destination or on-route based on the criteria that the user selects. The ADAS then routes the user directly to this CS, and then onwards to their other points of interest.

It is possible to reduce a users' decision time and communicate a preference for a particular choice (for example from project perspective), by setting a default. A default is defined as the option that is executed when no action is taken, i.e. when a person does nothing to switch to an alternative. For example, organ donation can be by default opt-in, i.e. one has to sign up to become an organ donor, or it can be opt-out, where one is an organ donor without any necessary action [27], [28]. Research has shown that defaults tend to stick; once a box is ticked by default, individuals are unlikely to untick it, and vice versa. This kind of intervention usually works best under uncertainty or when all choices are equal and the user has no motivation to make a specific choice. They can also be preset by the user themselves in the form of a self-nudge [29].

Lack of knowledge or understanding can also be targeted by giving users additional information. However, presenting information can be difficult, because it requires clarity, readability, and it has to be meaningful (evaluable) in order to increase adherence; for example, one could convey the way in which a users' behavior impacts the climate by showing a polar bear on a melting ice surface, or give comparative CO_2 values via tree offset representations [30]–[32].

Motivational or knowledge barriers can also be overcome by the introduction of game elements, commonly known as gamification [33], [34]. These count as choice architectural interventions in the sense that framing CO_2 savings in terms of points collected is a form of evaluative information, and setting up an avatar as eco-friendly is a form of self-nudge that can motivate one to later make more environmentally sustainable choices [35]. Social interactions or norms [36] can also be important factors; for example informing a person about the energy saved by their neighbor has been shown to positively impact future choices and behaviors [37], [38].

III. METHODOLOGY

The ELECTRIFIC ADAS is one part of the ELECTRIFIC solution, which also includes a smart charging system and a smart scheduler. Currently, the ADAS computes a route based on user inputs (the starting location and the destination, willingness to charge), and preferences such the desired route optimization (green or fast). From these inputs, a route is generated, received and displayed in the ADAS interface, with the following details: navigation, charging station (if applicable, due to selection by the user, and within a range of 500m of the destination), and the estimated energy consumption.

A greenness metric (calculated based on grid stability and congestion, energy efficient routing and renewables currently available, as well as real time information of traffic) will be calculated in following versions and displayed to the user, for example in the form of green points. A CO_2 parameter will also be calculated based on input from charging station providers (CSPs), including the current state of renewables from each charging station and the kwH per trip taken. Finally, a future version of the service will include suggestions of a CS along the route as well as near the destination point of interest.

The user receives a visualization of their trip on a map, and in the form of a route summary, and receives additional information about the charging station: the connector, the location and details such as payment and opening hours whenever available. Percentage of renewables will be shown in future iterations.

Defaults and evaluable feedback were selected as best suited to be integrated into the ADAS UI, and an incentive screen was designed, to be used for behavioral experimental trials in the ELECTRIFIC project, presented below. A second iteration of the ADAS seeks to integrate the chosen incentive structures within a map view for usability reasons, also presented below.

IV. Results

The current version of the ADAS is designed to allow for a single trip from origin to destination. Figure 1 showcases the input screen of origin and destination alongside a map to display the location of each.

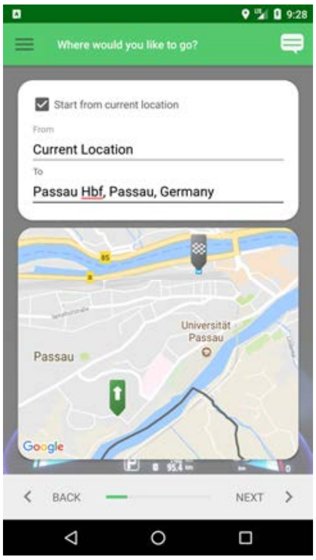

Figure 1: ADAS UI origin and destination input

In one version of the ADAS used for trials, a screen is then introduced allowing the selection of a green and fast route. Users see by default a preselection of either the green or fast route (randomized), with an active choice selection (empty dropdown) for the control group. Some users will also see incentives: financial or evaluable information.

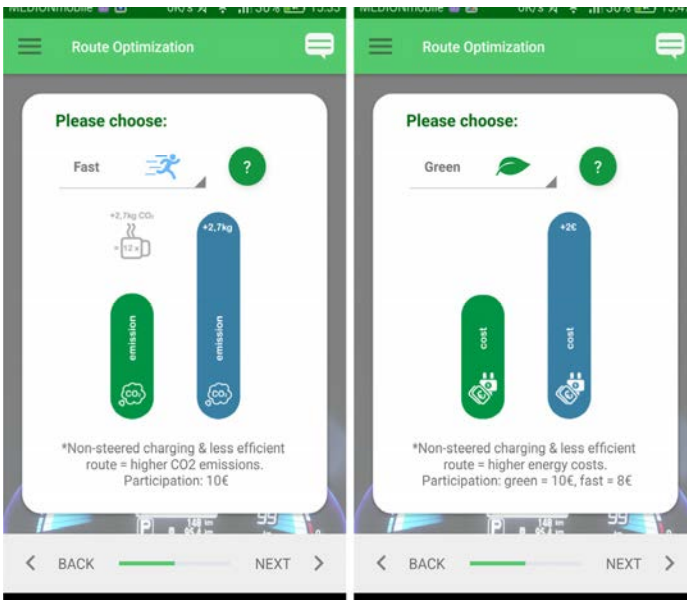

Figure 2: Symbolic (left) and financial (right) incentive screens; route optimization selection via dropdown, with either fast default (left) or green default (right)

Figure 2 displays the designed incentives; if they are assigned the symbolic incentive, users see that less CO_2 in kg is produced on the green route, made evaluable via the form of cups of coffee that can be produced with the same amount of CO2. If they are assigned to the financial condition, users are informed that due to non-steered charging and less energy-efficient routing, the fast route is costlier.

As we are testing the effects of a hard default, users see a map which only shows their selected route, see Figure 3. Changing the route selection to another optimization criterium is intentionally made more difficult to increase the effectiveness of the default. This will be compared to the implementation of a soft default in the next version of the ADAS (Figure 4). In addition to the map view, users can refer to a route summary screen as well.

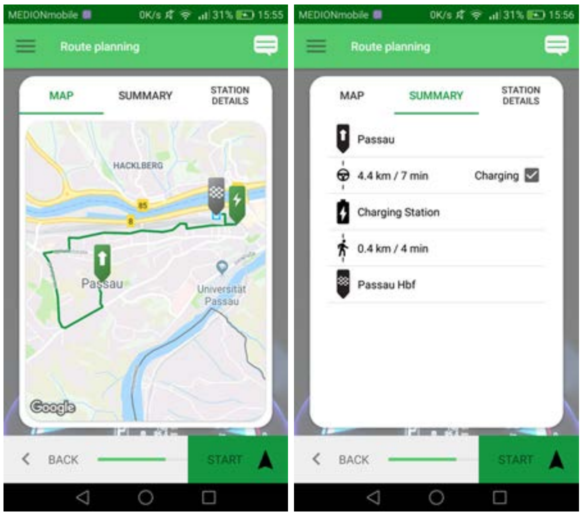

Figure 3: Map view of the selected route (left) and route summary (right) including toggle of charging station

In the version of the ADAS following first trials, the incentive screen will be removed, and for the second trials, users will be presented a default on the map screen only, as can be seen in Figure 4. Either the green or the fast route is set as a default and highlighted via the coloring of the route – the green route default can be seen in Figure 4.

Figure 4: ADAS UI green soft default route

Figure 5 shows a first implementation of the symbolic incentive for the map-based ADAS. A tag will appear when the user selects the fast route, informing them about the increase in CO_2 for this route. Similarly, in a different tag, financial information will be displayed if one of the routes is cheaper. Information about the length (in km) or time (in min) of the trip is always visible to users in the route summary below the map which can be swiped up.

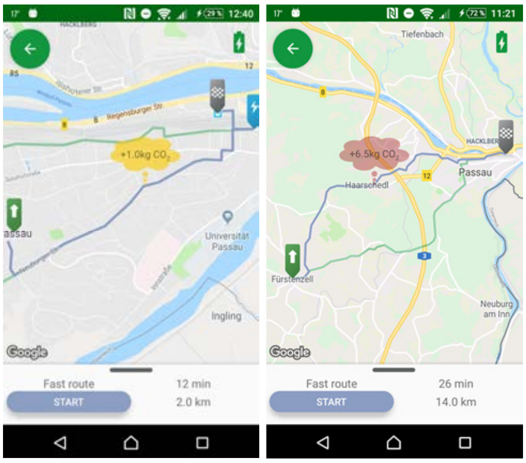

Figure 5: Fast route selection on map, with tags showing amount of additional CO2 necessary for route completion; low (left) and high (right) amounts are emphasized via color codes

Multiple experimental field trials are planned for the project where the here displayed incentives will be tested in randomized controlled trials. Interventions will be compared against results from control groups to make accurate predictions about the effectiveness of the choice architecture implemented, and to better judge which behavioral steering techniques show the most promise for long-term implementation. For example, we will attempt to compare the effect of the hard default as it is implemented through the incentives screen (users have to return to this screen to change their route selection) with the effect of the soft default as it is implemented through the map interaction where users can choose the other route as it is directly available.

The final solution of the ELECTRIFIC ADAS will be optimized for whole-day scheduling. This will include the upload of schedules and appointments, and implementation of recurring events and locations to optimize routing and charging in a fast, green or cheap way. The engagement with the users via behavior steering techniques is applicable across such changes to UI; depending on the findings from single-trip trials, the designs will be adapted to best suit the needs of the stakeholders.

V. Discussion

The current mobility environment does very little to steer drivers of all vehicles towards a more coordinated approach of behaviors, in this manner forming individual habits that can have enormous benefits for the entire system in the long-term. And while it has been argued that pricing is often used by governments and service providers to affect demand, for example in an attempt to reduce electricity or gasoline consumption, this has been found to have mixed effects, especially as a longer-term intrinsic incentive strategy, sometimes oppositely resulting in rebounds instead where even more consumption is recorded after such interventions occur [39]–[41]. Other behavior steering techniques will need to be explored to find optimal strategies to change patterns of behaviors.

Drivers of vehicles are not used to coordinated charging, or navigation systems that provide smart routing and charging solutions. After they make the switch to an electric vehicle, EV drivers then charge in an erratic, uncoordinated manner, often strongly affected by range anxiety that is caused by the perception that the depletion of EV batteries is unpredictable [42], [43]; or they charge habitually when they return home from work, when everyone else charges and the grid is already facing large loads. Substantial increases of the system peak load for 2020 and 2030 are part of projection scenarios if these patterns continue [44].

If it is expected that EV users will eventually play an active role in overcoming these issues, then it is important to realize that currently, products and services are not designed to support this kind of active role; and a lack of insights into processes of behavioral change will further lead to a failure in integrating the changes necessary to make a system a reality in which users have the skills and motivation to play this role [45]. Changing behaviors therefore becomes one of the main issues in managing grid stability and increasing the proportion of renewables in the battery.

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