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EV Explorer: Evaluating a Vehicle Informational Tool

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ABSTRACT

This paper reports the evaluation of EV Explorer, an online vehicle informational tool. EV Explorer allows users to compare fuel costs for different vehicles based on their own commuting patterns, charging opportunities, vehicle mileage, and local fuel prices. All these inputs can be adjusted by the user for a tailored estimate of annual fuel costs for up to four user-selected vehicles at a time. Default vehicle comparisons promote consideration of plug-in hybrid electric and fully electric vehicles (PEVs). We evaluated EV Explorer through online experimentation, gauging users' perceptions—before and after using the website—of their current fuel costs, potential savings with PEVs, attitude toward PEV charging, and intention to buy or lease a PEV in the future. Statistically significant changes in each of these variables validate EV Explorer as an educational tool and a persuasive eco-feedback intervention to promote the adoption of PEVs.

EV EXPLORER

EV Explorer [7] is an online vehicle informational tool that allows users to explore fuel costs and charging requirements for different vehicles tailored to their particular commute patterns. EV Explorer has had over 19,000 users and been promoted and utilized by government, industry, and various media outlets.

Website Development

EV Explorer is written entirely in JavaScript. It uses Node.js [6] to power its webserver and API. It also makes use of several freely available public APIs. The map-driven content is powered by Google Maps [5]. This includes geocoding and route generation in addition to the standard map display. Vehicle information concerning fuel economy and range comes from an API available from the United States (US) Department of Energy's Office of Energy Efficiency and Renewable Energy [9]. EV Explorer provides relevant fuel prices to the user by combining data from the US Energy Information Administration [1] with the user's location from freegeoip [2] based on their IP address. Electricity price was not created dynamically; it was set at \$0.14 USD/kWh, which was slightly higher than average electricity price in the US in 2015. Because EV Explorer is a JavaScript based tool, all of the calculations are done right in the user's browser, which makes the tool very responsive to use.

User Interface Flow and Features

Upon first entering the site, EV Explorer prompts the user through two steps. 'Step 1' is to enter a home address by either typing it in or dragging a marker to the location on the map in the background (Figure 1). 'Step 2' is to enter a commuting destination in the same way. Upon completion of these two steps, a stacked bar chart comparison of annual energy costs for four vehicles is presented: one gas only, one plug-in hybrid electric, and two fully electric vehicles (Figure 2).

The user can explore other features, such as changing the frequency of the commute (default is 5 days per week) and charging opportunities at destination (Figure 3). 'Car Manager' allows the user to select up to four different cars to compare, and allows modification of mileage, range, and time to charge (Figure 4). Another feature allows the modification of gas and electricity prices (Figure 5).

Present Research

EV Explorer can be considered a type of eco-feedback, defined by Froelich, Findlater, and Landay [3] as feedback on individual or group behaviors with a goal of reducing environmental impact. Though EV Explorer does not explicitly attempt to persuade users to adopt plug-in hybrid electric vehicles (PHEVs) or fully electric vehicles (EVs)—together referred to as PEVs, the focus on fueling costs and default car comparison that juxtaposes a gas vehicle with three PEVs serve to highlight a major benefit of PEVs, fueling costs. Other vehicle attributes consumers may value, such as aesthetics, performance, utility, safety, and purchase or lease price, are not addressed in EV Explorer.

Gardner and Stern [4] made a useful distinction between two types of energy-saving actions: curtailment (habitual low cost behaviors) and efficiency (investments in equipment or structural modifications). While most eco-feedback targets curtailment behaviors [3], EV Explorer targets an efficiency behavior: adoption of a fuel-efficient vehicle. Froelich et al. [3] suggest the importance of addressing efficiency behaviors in eco-feedback since the savings associated with efficiency behaviors is typically much higher than that associated with curtailment behaviors. The present study evaluates EV Explorer as a form of eco-feedback targeting efficiency behavior by measuring its effect on users' knowledge of, attitudes toward, and intention to adopt PEVs.

Froelich et al. [3] note that most evaluative research on eco-feedback in the field of HCI is qualitative and informal, with small sample sizes, focusing on usability and user experience. Few HCI eco-feedback studies have employed field tests, with large sample sizes, experimental designs, and a focus on behavior change. The present study describes a low resource large-scale experimental field research methodology that HCI researchers can easily adopt into their eco-feedback evaluation procedures.

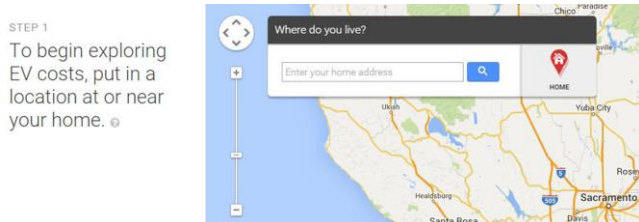


Figure 1. Step 1: Enter home address.

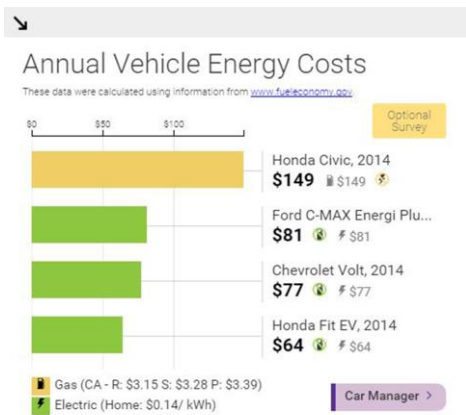


Figure 2. EV Explorer output.

Figure 3. Commute frequency and charging opportunities.

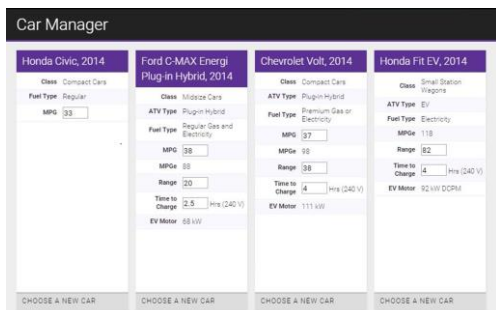


Figure 4. Car manager and MPG/range/time to charge.

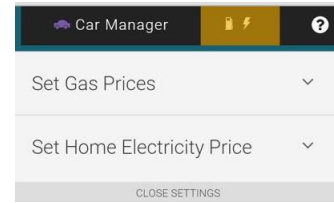


Figure 5. Gas and electricity prices.

METHODOLOGY

An experimental survey instrument was developed using SurveyMonkey. Users were asked a series of identical questions before and after receiving a link and prompt to visit EV Explorer. This design provided a direct measurement of change in knowledge of, attitudes toward, and intention to adopt PEVs before and after experiencing the website. The before-and-after questions were as follows:

- About how much money do you spend on gas and/or electricity to fuel your vehicle(s)? Please enter both a dollar amount and unit of time (e.g., \$100/week).
- Given your driving patterns, how much would/do you save in fueling costs by driving the following vehicle types compared to a gas only vehicle? (hybrid, plug-in hybrid electric, electric)
- Given your driving patterns, how (in)convenient are the charging requirements of the following vehicle types compared to fueling a gas only vehicle? (plug-in hybrid electric, electric)
- How likely are you to buy/lease the following vehicle types in the future? (gas only, hybrid, plug-in hybrid electric, electric)

In order to identify intervening variables that help explain any observed changes in the dependent variables described above, users were asked which website features they used and what calculations they made while exploring the site (i.e., how much they would spend or save by driving their current vehicle or a different vehicle), as well as demographic questions (age, sex, income, education, and political ideology).

Questions were developed using Roger's [8] diffusion of innovations as a theoretical framework. Rogers describes an innovation-decision process by which an individual decides to adopt, reject, continue, or discontinue an innovative technology. This process consists of five stages: knowledge, persuasion, decision, implementation, and confirmation.

Implementation

The experimental survey tool was deployed on Amazon Mechanical Turk. A sample of 108 Mechanical Turk "workers" participated by answering every required question. Participants were paid \$0.65 USD. Average time spent exploring the site and answering questions was approximately 15 minutes.

RESULTS

Participants included 63 males, 44 females, and one "other". Their average was 32, ranging from 19 to 62, with a standard

deviation of 10 years. Participants' median household income was \$25,000 to \$49,999 and their median level of education was a Bachelor's degree. Median political ideology (rated from extremely conservative to extremely liberal) was 'slightly liberal'. Participants indicated the type(s) of vehicles they drive on a regular basis; 100 out of the 108 participants indicated that they drive a gas vehicle, 8 drive a hybrid, 5 drive a PHEV, and 0 drive an EV.

How Participants Used the Tool

Participants most frequently reported that they used each feature previously described: car manager (81%), commute frequency (79%), charging opportunities at commute destination (52%), mileage/range/time to charge (55%), and fuel/electricity prices (65%). Participants were encouraged to go back and use features that they may not have noticed independently. Whether they noticed the feature independently or not was distinguished in the survey, thus the results yielded design implications for a need to improve the saliency of some features.

Participants most frequently selected to view and/or compare a vehicle they or someone in their household currently drives (52%), followed by a vehicle they are considering getting in the future (44%), a "dream" vehicle (30%), a vehicle they shopped for before deciding on current vehicle (14%), and a vehicle they or someone in their household used to drive (8%). Most commonly selected vehicle types were gas (69%), followed by hybrid (37%), EV (32%), and PHEV (28%). Figure 6 shows breakdown of this information.

The most common calculation participants made was their current fuel costs (72%), followed by what their cost would be with a different car (67%), what their savings would be with a different car (64%), and what their savings is with their current car compared to a different car (15%); only 5% reported making none of these calculations.

Experimental Findings

Paired t-tests were conducted using SPSS statistical software to analyze differences in participants' mean scores of responses before and after using EV Explorer.

After using EV Explorer, participants, on average, framed their fuel costs over longer periods of time; i.e., they chose to report their fuel costs in terms of months or years rather than weeks; $t(103) = -3.304, p = .001$ (Figure 7). After using EV Explorer, fewer participants reported being "not sure" about the savings associated with alternative vehicle types (Figure 8). For participants who had some perception about savings before using EV Explorer, their estimation of savings significantly increased for each: hybrids [$t(89) = -4.240, p < .0001$], PHEVs [$t(85) = -4.158, p < .0001$], and EVs [$t(84) = -3.848, p < .0001$]; Figure 9.

The experience of EV Explorer promoted a positive shift in attitudes toward vehicle charging for both PHEVs [$t(106) = -1.382; p = .170$] and EVs [$t(105) = -2.699; p = .008$]; Figure 10.

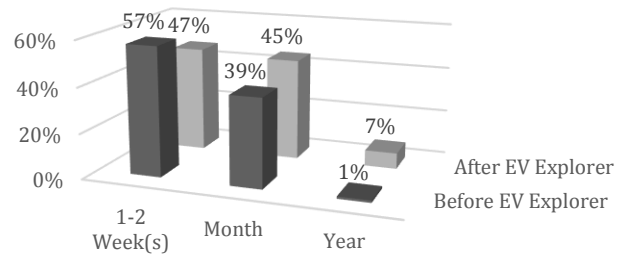


Figure 7. Time unit participants used to frame their fuel costs.

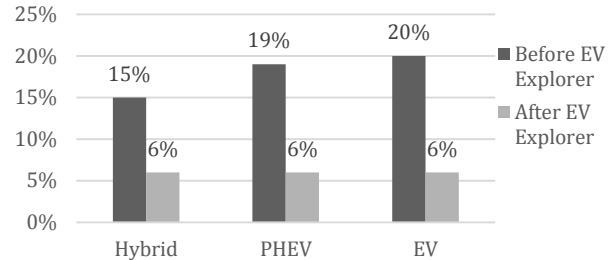


Figure 8. Participants "not sure" of personal savings associated with alternative vehicles.

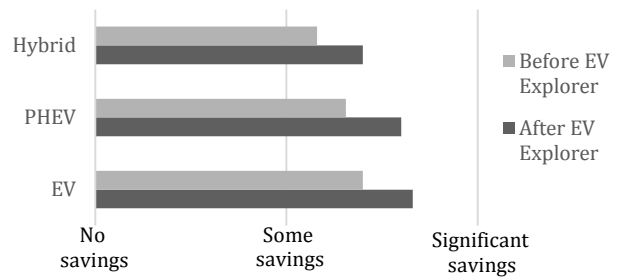


Figure 9. Perceived personal savings associated with alternative vehicles.

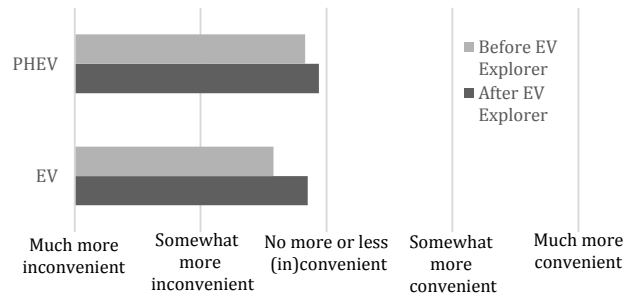


Figure 10. Attitude toward PEV charging compared to fueling a gas vehicle.

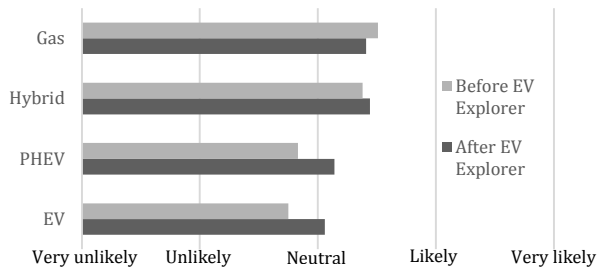


Figure 11. Intention to buy or lease each vehicle type.

Participants reported a significantly greater intention to buy or lease PHEVs [$t(107) = -4.603$; $p < .001$] and EVs [$t(107) = -4.077$; $p < .001$] after using EV Explorer; Figure 11. In both cases, mean scores in intention to buy or lease crossed over the line of neutrality from the negative side of “unlikely” before using EV Explorer to the positive side of “likely” after using EV Explorer.

Intervening Variables

Demographic and user behavior were related to change scores for the main experimental variables. Age correlated negatively with change in intention to buy or lease an EV, i.e., older participants’ intentions toward EVs were less malleable; $r = -.296$, $p < .01$. Household income correlated negatively with change in perceived personal savings associated with driving an EV; i.e., participants with higher incomes had less malleable perceptions of the significance of personal savings associated with EVs; $r = -.201$, $p < .05$.

User modification of commute frequency predicted a positive shift in attitude toward PHEV charging [$t(105) = -2.165$, $p = .033$], as well as an increase in perceived personal savings associated with driving an EV [$t(26) = 2.129$, $p = .043$]. Modification of fuel/electricity prices predicted a decrease in intention to buy/lease a gas vehicle; $t(106) = -2.016$, $p = .046$. Participants who calculated the cost of driving a different vehicle had a greater positive shift in attitude toward EV charging; $t(104) = -3.302$, $p = .001$.

Changes in perceived savings and attitude toward charging help explain the increase in intention to adopt PEVs. Increases in perceived savings associated with each hybrids, PHEVs, and EVs correlated positively with increase in intention to adopt PHEVs ($r = .227$, $.267$, $.214$, respectively, $p < .05$). A positive shift in attitude toward charging PHEVs correlated positively with increase in intention to adopt PHEVs; $r = .200$, $p = .039$.

DISCUSSION

According to this evaluation, EV Explorer is successful as both an educational tool and a persuasive eco-feedback intervention. Users learn about the fueling costs and charging requirements they could expect with alternative vehicles given their own driving habits. This knowledge promotes a positive shift in attitudes toward and intention to adopt PEVs.

It is important to understand the mechanisms involved in the user experience that led to these changes in knowledge, attitudes, and behavioral intention. These intervening

variables include the use of features allowing modification of commute frequency and modification of gas and electricity prices, as well as the calculation of cost of driving a different vehicle. Results also suggest that change in intention to adopt PHEVs is mediated by (a) changes in perceived savings associated with alternative vehicles and (b) changes in attitudes toward charging PHEVs.

Future design iterations of EV Explorer should incorporate information about other vehicle attributes, such as purchase/lease prices and aesthetics (include images of vehicles), for a more comprehensive tool. Changes in design to make features more salient should also be considered. Future research should test EV Explorer with different populations and after incorporating more vehicle attributes. A larger sample size could reveal more detailed relationships among intervening and outcome variables. Finally, eco-feedback designers and researchers should consider other opportunities for promoting efficiency behaviors.

CONCLUSION

By providing comparisons of energy costs and charging requirements for different vehicles based on the user’s own commuting context, EV Explorer is an informational tool that empowers consumers with the knowledge to decide whether alternative vehicles would work for them. This knowledge can be persuasive, as demonstrated by users’ increased intention to adopt PEVs after experiencing EV Explorer. This research demonstrates two concepts that are important for eco-feedback design and evaluation in HCI: a focus on efficiency behavior and a precedent for low resource experimental evaluation methodology.

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