In-vehicle ecodriving interface: Theory, design, and driver responses

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ABSTRACT
Ecodriving—the adoption of driving styles that reduce energy consumption—has long been recognized as a potential source of reductions in transportation energy use. However, estimates of energy savings range widely—from less than 5% to as high as 20% depending on the driving and experimental context. To explore whether in-vehicle energy feedback prompts and supports ecodriving, an energy feedback interface was designed based on the precepts of the Theory of Planned Behavior and the Extended Model of Goal Directed Behavior. This paper presents the results of interviews with 46 Plug-in Hybrid Electric Vehicle (PHEV) drivers who were given the ecodriving feedback interface for a multi-week trial including interface off and on conditions. Analysis of driver interviews suggests that theory-based feedback can encourage ecodriving. Specific findings include the following:

- the context of information feedback affects both comprehension and motivation;
- personalization of information allows different drivers to access pertinent information;
- instantaneous performance feedback is used primarily for experimentation and learning of new ecodriving behaviors;
- average performance feedback is used primarily for goal-setting and goal achievement; and,
- the direct comparison of personalized driver goals and average performance created a game-like experience that encouraged high achievement.

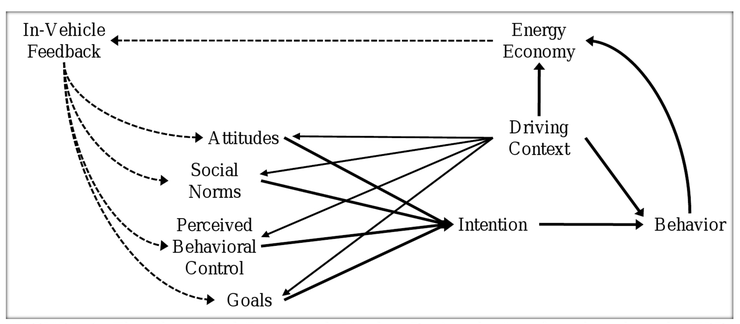

FIGURE 1 The Theoretical Framework Used to Design the Interface, based on the TPB and EMGDB (shown using solid lines) adapted to the driver behavior context for this study. The closed-loop feedback system created by the introduction of in-vehicle feedback is shown using dotted lines.

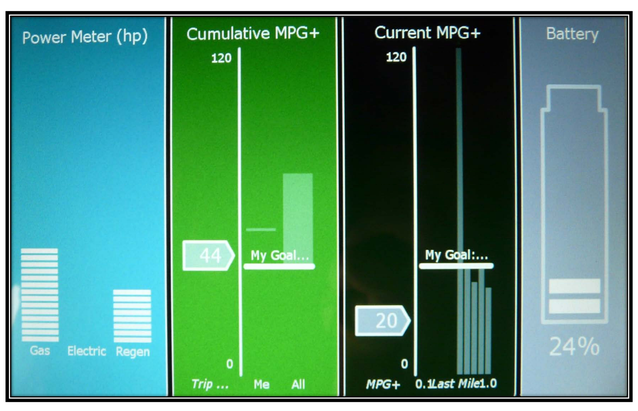

FIGURE 2 Example Interface Layout during "Interface On" Period

Trip- Average MPG+

I would only look at it towards the end of my trip, saying, okay, this is what it was for my trip. It wasn't as needed, not necessarily needed but you just didn't look at it as much because it was what it was. And so you really didn't change how you were driving versus when you were looking at the [current MPG+]...

It was a game for me. I started seeing it. I just wanted to get -- Because then I had your cumulative MPG plus and I just tried to get that as high as I could.

Yeah. Like a little game in a sense. You say, okay, how can I drive to get it up to 70 miles per gallon or whatever.

Real-Time MPG+

[the interface] tells me a lot here about what acceleration does in terms of mileage. I mean, I knew that intellectually, but, again, to have that visual feedback it was really quite striking. It was powerful for me.

It did cause me to move my indicator on the mode on the Sequoia from just telling me the temperature outside and what direction I'm driving to, what is my instant gas mileage.

I preferred the [instant feedback] because it was constant and it was right now. It gave me current information... it was like, okay, you know, you're down here possibly below 40 what are the conditions and how can you change ... to get that higher?

And even when I went up a small hill I would decelerate more, because normally, I mean, if I'm driving any other vehicle I'll usually keep it so that my speed is the same, and I'll obviously make the car work harder, whereas when I saw exactly what my numbers were on the Prius I would decelerate when going up even minor hills just to keep my efficiency up, regardless of my speed.

Cost Information

I remember seeing that, so that's not a lot, and I said, wow, a whole dollar to do all this stuff. That's pretty good.

Generally I'm so busy I'm pushing to get from one appointment to the next, but, you know, it's like there was just times I left a little bit early for work and I could just kind of relax and watch those costs go down a little bit. It was fascinating to watch. I could see if you were on a real conscious level you could save money doing that.

Power Information

...it really helped when we had the second phase where you were showing us, you know, what was going on. And so it was kind of interesting, sometimes when I thought it was just running on battery it was running on gas. But I like to get it so that the thing would, you know, come up to the stop, and then I'll just kind of shut down and then take off real slow, see if I could hold that battery, run it the whole way.

Social Comparisons

I did like the fact that you had combined our scores against all the other users of the other cars that you have going. That I thought was interesting just comparing different driving styles.

That really wasn't as useful because for me it was just saying, okay, there's the range but you don't know what they were getting. And you really can't do anything about it so it was just like you can only worry about yourself...

CO_2 Information

It was interesting to see, okay, that's how many pounds of CO2 you put out, but I have no frame of reference as to what that equates to.

I'm really not familiar with how much CO2 a regular car puts out, so I wasn't too familiar with that.

RESULTS
Based on the behavioral theories TPB and EMGDB, we posit that driver feedback that incorporates goals, average and real-time information, and the presentation of information in social contexts will facilitate increases in MPG+. Drivers' perceptions of these relationships are explored in the analysis of the interview transcripts.

Results generally support that goal-setting and feedback directly on the energy economy measure MPG+ are responsible for the majority of positive driver responses to the interface and self-reports of behavior change. Neither social contexts nor translations of the energy economy measure into cost and emissions metrics figured prominently in the drivers' accounts.

To estimate how frequently each of the information types was used for ecodriving, statements were tabulated by category, e.g., real-time, trip averages, and personal goals. Repeated statements within each category were used to create a list of unique subject-category pairs. These tallies are illustrated in Figure 3 for an overall view of the driver interest level or engagement with those factors. Descriptions of ecodriving and distraction in response to the interface feedback are included in the overview to help frame the discussion.

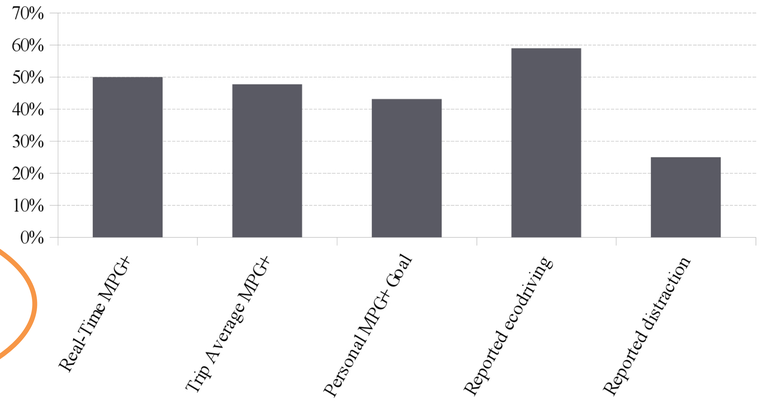

FIGURE 3 Percentage of driver responses indicating use of the interface for ecodriving behaviors by information type and overall. Responses are shown in percentages based on a total N of 44 individuals. For the behavioral factors (real-time, average, and goal information) only positive

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