DYNAMIC ECODRIVING IN NORTHERN CALIFORNIA: A STUDY OF SURVEY AND VEHICLE OPERATIONS DATA FROM AN ECODRIVING FEEDBACK DEVICE

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ABSTRACT

Ecodriving describes the behavioral modifications that drivers can make to improve their fuel economy. Dynamic ecodriving comprises the use of real-time feedback information that informs the driver of vehicle performance. This study evaluates the performance of an aftermarket real-time feedback device that reported instantaneous fuel economy to drivers while driving. Study participants (N = 18) drove with the device for two months. During the first month, the device provided no feedback, but collected data on driving activity. During the second month, the device continued to collect data, but also provided the participant with feedback on real-time fuel economy. Participants could then use the information to self-teach how to improve their fuel economy. The participants took two surveys to evaluate their response to the device, and vehicle activity data was analyzed to ascertain the degree to which driving behavior changed. A majority (56%) reported in surveys that the device changed how they drove during the second month. Vehicle activity data showed that different participants modified different behaviors in response to the feedback. Nine participants made some reduction to their acceleration from a stop, and eight made some reduction in the magnitude of their deceleration to a stop. Eleven participants reduced their average highway speeds. Across the broader sample, average highway speeds declined from 65.9 to 65.4 mph. Overall changes observed in fuel efficiency were small across the sample, which when excluding outliers, constituted a 1.4% improvement in fuel economy.

KEY WORDS: ecodriving, before-and-after survey, driver feedback, fuel consumption, greenhouse gases

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INTRODUCTION

Ecodriving is broadly defined as a collection of behavioral modifications that drivers can make to improve their fuel efficiency. Ecodriving has gained attention in recent years with increased volatility in gasoline prices and can offer a means to immediately improve fuel economy without making changes to driving distances or vehicles owned. This "immediacy" of implementation has also garnered interest of public agencies charged with reducing emissions resulting from gasoline combustion. However, a core challenge of ecodriving is conveying the necessary information to the driver such that the practices are implemented appropriately and consistently.

Dynamic ecodriving feedback provides information directly to the driver during vehicle operation. This requires an in-vehicle device communicating regularly to the driver, usually as a visual interface embedded in or placed on the dashboard. Generally, aftermarket devices take information from the On-Board Diagnostics (OBD-II) port and process it to provide feedback to the driver. The driver may use this information to drive more efficiently. The type and format of information provided can vary across devices. At a minimum, devices report the instantaneous fuel economy to the driver in numerical and/or graphical form, which allows the driver to gradually learn which behaviors result in better fuel economy. Drivers responding to the feedback can then self-teach more efficient driving behaviors.

This study reports on the driver response to an aftermarket device that provides real-time feedback on instantaneous fuel economy. Researchers installed the device (called the Eco-way

Navigator) into drivers' vehicles recruited from the general population in the San Francisco Bay Area. Each driver participated for two months. During the first month, the device recorded data from the driver's OBD-II port, but did not provide feedback to the driver. The driver then returned to researchers to have the feedback component of the device activated. The driver then drove for a second month with the feedback active. In addition to the vehicle data collected from the device, the driver took surveys to get their reported response to the device.

To begin, the authors provide a brief literature review on recent work that has been completed on ecodriving during the last few years, building on a previous review completed by the authors (1). Following the review, we proceed to describe the study methodology, the results of survey and vehicle data analysis, and follow with conclusions from this analysis.

LITERATURE REVIEW

Research into feedback mechanisms to encourage ecodriving has increased dramatically over the past few years. A 2010 Fiat report analyzed data from over 42,000 European drivers—using the automaker's "eco:Drive" online program that tracks driving patterns, the analysis revealed a six-percent average reduction in fuel consumption and emissions (2). A 2011 study at the University of California (UC), Riverside equipped 20 Southern California drivers with the same feedback device as applied here and reported, on average, a six-percent improvement of fuel economy on city streets and one-percent improvement on freeways (3). The University of Tokyo published a paper the same year suggesting that ecodriving with an eco-indicator could reduce physical leg burden on drivers in addition to the gains in fuel economy (4).

Other studies have continued to confirm the potential benefits associated with effective ecodriving behavior. A 2011 University of Michigan report compared fuel economy savings across strategic, tactical, and operational levels of analysis. It was found that while longer-term vehicle selection decisions presented the single largest factor in determining a driver's overall fuel economy, poor route selection and vehicle operation choices could still decrease on-road fuel economy by as much as 45% per driver (5).

Fuel savings may depend on the driving environment and context, however. An Australian study using a microscopic traffic simulator found that the net effect of moderate and smooth acceleration during congestion was negative (6). A 2011 University of Groningen and French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR) driving simulator study set goals such as fuel efficiency or time saving for participants and followed up with interviews. The research showed significant decreases in ecodriving behavior in demanding traffic environments or under time pressure, suggesting that insofar as driving behavior is regulated by goals and motives, fuel efficiency is generally of lower priority when faced with competing time or safety imperatives (7). A South Korean study the same year evaluating feedback interface effects on the KIA Soul found no improvement during the drive portion with the interface on, with gains in fuel efficiency from the feedback device apparently offset by increased mental demands in the heavy-traffic simulated drive course (8).

Research has also been conducted on the driver interfaces of in-vehicle feedback systems, which have been widely assumed to be effective fuel-saving devices. A 2010 British paper noted that while fuel-efficient and safe-driving practices were often correlated, there remained potential for conflict. Thus, "smart" driving interfaces would have to effectively manage situational changes. It suggested that displays that presented the most information in the least visually-demanding way would present the best balance between driver attention and efficiency gains (9).

A 2011 Canadian drive simulator study using the Toyota Prius's ecodriving interface found that while hybrid interfaces increase ecodriving behavior, participants looked at the road 62% of the time with the interface and 74% of the time without it. Linking glances between the interface and speedometer also resulted in some glances exceeding 1.6 seconds in duration away from the road, lengths associated with higher crash risk (*10*). Researchers at UC Davis recently examined driver feedback interfaces in plug-in hybrid electric vehicles from the perspective of the theory of planned behavior. Based on final interview transcripts and subsequent statistical modeling, it concluded that interfaces focusing on energy economy and personal driver goals are likely to have greater behavioral impact than displays attempting to present the greater volume of information. The study also found that colors should be used with caution in displays, and that drivers seemed to prefer color gradients as opposed to shifts in color (*11*).

The United Kingdom-based Foot-LITE project published a paper in 2011 following drive simulator testing. It found that Ecological Interface Design (EID) feedback interfaces performed similarly in encouraging desired driving behaviors and did not add to driver distraction. In fact, the EID interface had advantages with increased peripheral attention and reduced subjective workload in an urban scenario (*12*).

Recent studies have employed modeling and algorithm technologies to refine ecodriving feedback interfaces. A June 2012 conference paper by IFSTTAR presented two logistic regression models for creating an aggregate "eco-index," a four-variable model based on eco-driving tenets as well as a positive kinetic energy model suitable for nomadic devices with lower computational power (*13*). Modeling from Clemson University last year using a Markov chain Monte Carlo simulation to predict lead-car driving patterns offers possibilities for smoother and more fuel-efficient adaptive cruise control systems (*14*). On the infrastructure side, a 2011 UC Riverside conference paper presented a dynamic ecodriving velocity-planning algorithm utilizing vehicle-to-infrastructure (V2I) communications technology to adjust vehicle speed through a signalized corridor that could improve fuel economy by 12% (*15*). A subsequent 2011 study found that an explicit fuel-minimization objective function in the mathematical modeling yielded more accurate fuel-optimal speed profiles for vehicles approaching the intersection than simplified objective functions (*16*).

This body of research represents a considerable expansion in activity in ecodriving, comprising work since 2010. As such, the exploration of ecodriving has moved from the conceptual phase in research to the development and field testing phase. The study that follows builds on this work in the latter category, describing the field test results of an aftermarket feedback device.

METHODOLOGY

UC Berkeley and UC Riverside researchers analyzed data from a longitudinal study of Northern California drivers. The researchers conducted recruitment and data collection from January to October of 2011. Participants were recruited from employees of nearby offices as well as the general driving population. Of the 24 participants who began the study, 18 completed the study, and 16 took both surveys.

Data Collection

A longitudinal "before-and-after" survey was developed and pretested, which participants completed at the beginning and end of their two-month period in the study. The before-survey was given to respondents before they received the device. This survey asked questions concerning existing driving practices, to establish a baseline to compare to the after-survey. Researchers then installed the Eco-way Navigator, a data collection and driver feedback device, into participants' personal vehicles, connected through the OBD-II connector. This device collected vehicle operations data under normal driving conditions over the course of two months (eight weeks). At the beginning, the device had a locked screen and could not provide feedback to the driver. Halfway through the study (after one month), the feedback screen was unlocked to display real-time feedback to the driver. Drivers were then trained on how to read the feedback, which consisted of two metrics on color-coded graphs—1) instantaneous fuel economy in miles per gallon (MPG), and 2) carbon dioxide emissions in pounds per mile (lb/mi) (calculated from fuel consumption) as shown in Figure 1.

Figure 1 Feedback screen of the Eco-way device.

Participants then drove for a month while the device collected data and displayed feedback. Drivers could use the feedback at their discretion. The study participants were the only drivers in the respective vehicles during the data-collection period. At the end of the eight weeks, drivers returned the device and were administered the after-survey. This survey asked about any changes in their driving behavior and perceptions of the feedback device.

Vehicle Operations Data Analysis

The data collection and feedback device collected vehicle operations data is aggregated by the device over two-second intervals, as well as in "per-trip" summaries. Key data collected include vehicle velocity, odometer, vehicle RPM, fuel consumption, and instantaneous fuel economy, all with a timestamp.

Study Limitations

This study had limitations that should be understood in the context of the results. One limitation was the small sample size (N = 18). Recruitment for the study from the general population was a challenge, and a single person was involved for two months to complete the study. A number of events could happen during that period that would invalidate participant data. For example, the study lost two participants due to a vehicle break-in and theft of devices. Another limitation to generalizations is a population that was reflective of the socio-demographics of the San Francisco Bay Area, which is not representative of the broader state or nation. In addition, the study constitutes an uncontrolled deployment of the devices. In this sense, other factors could and did influence vehicle fuel economy. We cannot conclude that observed changes are uniquely and solely the result of the feedback device. Rather, we look for changes in behavior that are expected to emerge from feedback, and evaluate whether those changes correspond to observed improvements in fuel economy.

RESULTS

The fuel consumption data recorded by the device found that 11 respondents (65%) exhibited an increase in fuel economy while a remaining 6 (35%) exhibited a decline in fuel economy. The fuel economy data from one participant was discarded because he reported towing something during the first month. The results that follow are divided into two sections. First, the authors provide a review of the survey results, including sample demographics, as well as before-and-after responses from participants as collected through the longitudinal survey. The second section takes a closer look at the vehicle operations data to identify behaviors that were observed to change among those that improved fuel economy in comparison to those that did not.

Demographics and Vehicles Driven

The sixteen participants who completed the two surveys exhibited characteristics reflecting demographics of the Bay Area (*17*). Half of the participants' household incomes were over $75,000. The education level was higher than that of the Bay Area's, with over 80% having a bachelor's degree or higher. Half of the participants stated they were Caucasian, slightly higher than the Bay Area population; Asians were overrepresented, and Hispanics were underrepresented. Table 1 presents key demographics of the participants.

Table 1 Longitudinal Survey Demographics

2010 Household Income	*Count*	*%*	*Bay Area %*
Less than $10,000	1	6%	5%
$10,000 to $15,000	0	0%	5%
$15,000 to $25,000	0	0%	8%
$25,000 to $35,000	0	0%	7%
$35,000 to $50,000	3	19%	11%
$50,000 to $75,000	1	6%	16%
$75,000 to $100,000	1	6%	12%
$100,000 to $150,000	4	25%	17%
$150,000 to $200,000	3	19%	9%
More than $200,000	0	0%	11%
Decline to Respond	3	19%	--

Education	*Count*	*%*	*Bay Area %*
Grade School	0	0%	7%
Graduated High School	0	0%	18%
Some college	2	13%	19%
Associate's Degree	0	0%	7%
Bachelor's Degree	10	63%	27%
Master's Degree (MS, MA, MBA, etc.)	2	13%	17%
Juris Doctorate Degree (JD)	0	0%	
Doctorate Degree (PhD, EdD, etc.)	1	6%	
Medical Degree (MD, etc.)	0	0%	
Other	1	6%	--

Household Category	*Count*	*%*	*Bay Area %*
Self only	1	6%	29%
Self with spouse/partner	5	31%	25%
Self with spouse/partner and child(ren)	7	44%	21%
Self with child(ren)	0	0%	7%
Self with roommate(s)	2	13%	8%
Other, please specify:	1	6%	--

Gender	*Count*	*%*	*Bay Area %*
Male	8	50%	49%
Female	8	50%	51%
Total	16		

Race	*Count*	*%*	*Bay Area %*
Caucasian	8	50%	42%
Hispanic	0	0%	22%
African-American	1	6%	8%
Asian	6	38%	23%
Native American or Alaskan Native	0	0%	0%
Hawaiian or Pacific Islander	0	0%	1%
Mixed Race	1	6%	5%
Decline to Respond	0	0%	--
Other	0	0%	--
Total	16		

In addition to the demographics, the vehicles driven by respondents are important participant attributes of the study. As the device could be attached to most vehicles (hybrid and non-hybrid), the type of vehicle receiving feedback was subject to some diversity. Table 2 illustrates the vehicles that participated in the study by make, model, and year as well as information on the miles driven during the study period, and observed change in fuel economy.

Table 2 Vehicles Driven By Participants in the Study (*N* = 17)

Year	Make	Model	Total Distance Traveled (mi)	EPA Combined Fuel Economy (MPG)	Increased/ Decreased Fuel Economy	Percent Change in Fuel Economy
2000	Honda	Accord	2137	23	Decreased	-26%
2000	Toyota	Camry	2750	23	Decreased	-5%
2000	Toyota	Corolla	3436	26	Decreased	-3%
2001	Chevrolet	Tracker	1206	22	Increased	1%
2001	Saturn	SC	2426	26	Increased	1%
2003	Toyota	Camry	1517	24	Decreased	-4%
2003	Toyota	Corolla	2101	28	Increased	6%
2004	Honda	Civic Hybrid	2585	40	Increased	4%
2005	Scion	Xb	2173	29	Decreased	-5%
2005	Toyota	Matrix	5331	27	Decreased	-2%
2007	Chevrolet	Cobalt	633	23	Increased	25%
2007	Toyota	Prius	1937	46	Increased	1%
2007	Volkswagen	Jetta	2997	25	Increased	1%
2008	Subaru	Forester	1659	22	Increased	1%
2008	Volkswagen	GTI	449	25	Increased	5%
2009	Toyota	RAV4	5918	24	Increased	6%
2010	Hyundai	Elantra Touring	1452	26	Increased	9%

The data in Table 2 is sorted by model year and shows that all the vehicles in the study were eleven years old or younger. Also evident from Table 2 is a moderate inverse correlation between the change in fuel economy and vehicle age. Two of the participants exhibited fuel economy changes that were considered outliers (e.g., -26%, +25%). Even with these large changes, which are likely not attributable to the device, vehicle data can still show whether there exist specific ecodriving behaviors that occur in response to the feedback. The correlation coefficient between vehicle age and fuel economy improvement, with outliers excluded, was -0.597.

Longitudinal Survey

The survey captured the before-and-after stated responses of the participants, particularly their change in driving behavior and fuel usage due to the feedback device. The results suggest that the real-time feedback influenced some drivers' behaviors, while it was ineffective for others.

The after-survey posed several questions regarding drivers' stated response to the feedback device. Table 3 shows the responses to the question, "Because of the Eco-way , I […]", based on a four-point Likert scale—"strongly agree," "agree," "disagree," or "strongly disagree." Over half (56%) of participants stated that they changed their driving behavior due to the feedback device, while the remaining 44% stated they did not. When asked about the specific driving patterns altered, 57% of participants also stated that they accelerated at a slower rate because of the feedback device. Similarly, two-thirds thought they coasted more. Despite these perceived changes, on self-perceived fuel consumption, 57% did not think their second month (with real-time feedback) saved more fuel than their first month (without real-time feedback). All drivers believed they achieved no time savings because of ecodriving, due to the slower speeds necessary for achieving fuel savings.

Table 3 Driver Stated Response to Real-Time Feedback Device

Response	Because of the Eco-Way I...						
	Changed how I drove during the 2nd month of the study.	Would accelerate slower.	Would coast more often.	Would brake more gradually.	Would drive at a slower speed on the highway.	Consumed less fuel during the 2nd month than I did during the 1st month.	Would get to where I am going faster than I did before.
Strongly Agree	6%	19%	47%	13%	19%	6%	0%
Agree	50%	38%	20%	31%	38%	38%	0%
Disagree	38%	25%	13%	38%	38%	44%	50%
Strongly Disagree	6%	19%	20%	19%	6%	13%	50%
Respondent Total	16	16	15	16	16	16	16

While feedback devices may provide a benefit to drivers, they could also serve as a distraction to drivers. To evaluate this, the after-survey asked two questions regarding driver distraction that might result from the device. Respondents were asked, “To what extent did you find the device to be a distraction from your driving?”. About 20% (n = 3) felt it was not a distraction, over half of respondents (n = 9) stated it was a minor distraction, 13% (n = 2) felt that it was a moderate distraction and another 13% (n = 2) felt that it was a significant or very significant.

Next, to evaluate distributional shifts in driving behavior, several survey questions were asked in both the before-survey and after-survey. This dynamic is illustrated in Figure 2, with before-distributions in dark gray, and the after-distributions in light gray. The top-left graph presents the responses to the question, “When driving your primary vehicle, how often do you adjust your driving behavior in ways to improve your fuel economy?” The mode of the distribution before using the feedback device was a response of “sometimes.” After using the feedback device, the mode shifted right to both “sometimes” and “often.” The top-right graph shows the responses to the question, “When you drive on the freeway without traffic congestion (such as I-580, I-80 or US 101), what cruising speed do you typically try to maintain?”. The mode response without feedback was 70 mph (113 km/h), while the mode for speeds after two months was 65 mph (105 km/h). This reduction in highway speed was also validated by the vehicle data presented in the following section. The bottom-left graph shows reported shift to slower acceleration. Interestingly, stated braking behavior shifted slightly toward less gradual braking, but still gradual, shown in the bottom-right graph. Thus the survey suggests that the feedback device may have had more impact on driver acceleration than on braking.

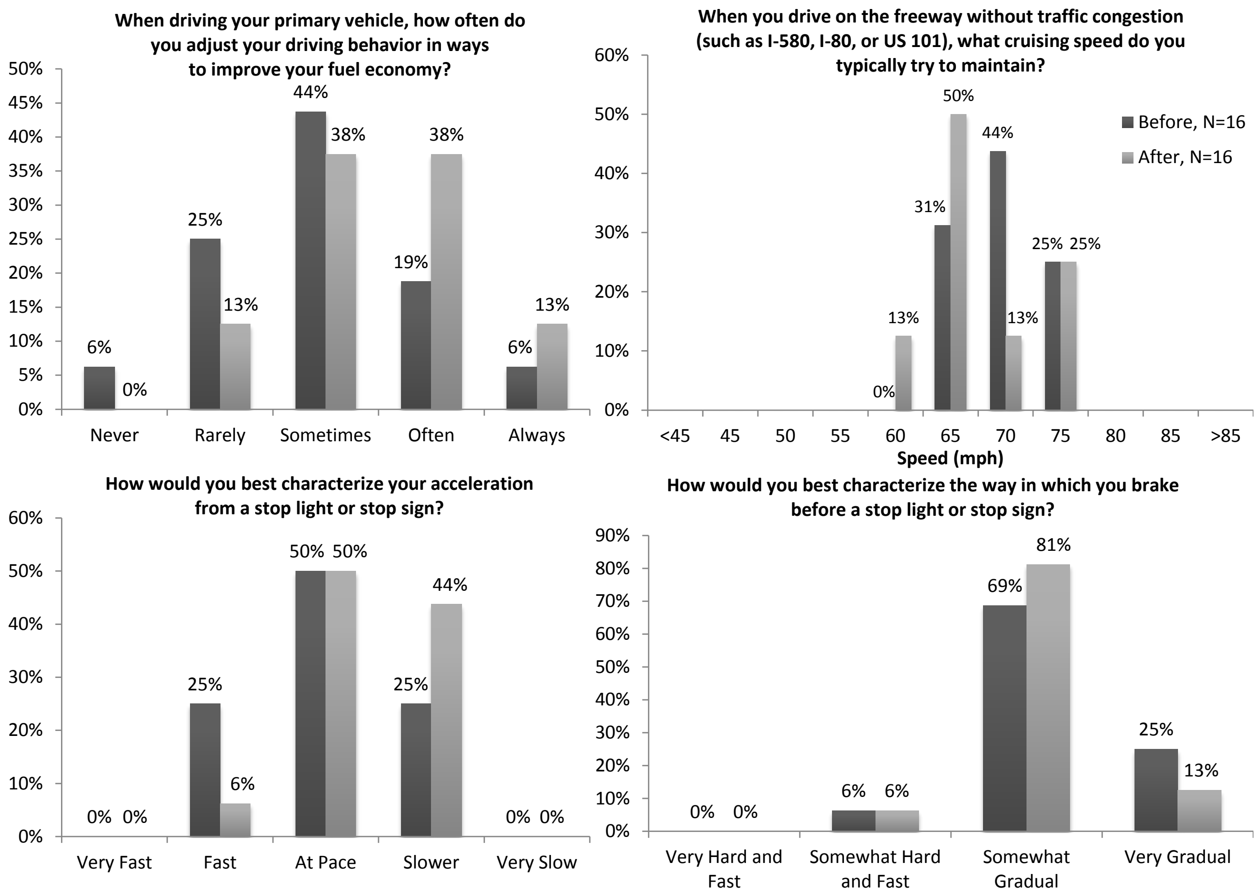

Figure 2 Distributional shifts in driving patterns.

In order to determine the statistical significance of these shifts in driver behavior, the authors employed the non-parametric, Wilcoxon signed-rank test. This test is most useful for ordinal variables and in cases when the sample is small (less than 30). Both conditions are met with this data. Of the four paired questions above, three were statistically significant at the five-percent level. Self-perceived driving behavior adjustment (Figure 2, top-left graph) was statistically significant ($p = 0.049$), with a rightward shift towards more frequent adjustment. Additionally, acceleration from a traffic signal (Figure 2, bottom-left graph) was statistically significant ($p = 0.029$), shifting rightward towards slower acceleration. Finally, the decline in reported highway speeds was also statistically significant ($p = 0.048$) at the five percent level (Figure 2, top-right graph). Only the limited reported change in braking appeared to be insignificantly different before and after the use of the device.

Lastly, to determine effectiveness of the feedback device on actual fuel use, fuel consumption data as reported by the Eco-way was compared between the first and second month. The vehicle-based fuel economy data is shown in Figure 3. The top graph shows a distribution with about 65% of participants improving fuel economy and the remaining 35% experiencing a decline. Figure 3 has a sample of 17, as the previously mentioned outlier (a 29% improvement) was dropped. Two additional outliers of similar magnitude are evident, and are not the result of feedback alone. While the measured changes in fuel economy are important, the nature of the deployment allowed other factors to play influence. This is true for all participants, which could have measured both improvements and reductions in fuel economy for exogenous reasons, while at the same time influenced positively by the device. Overall, non-outlier participants that improved their fuel economy (*n* = 10) did so with an average of 3.4% increase, while across the entire sample, the non-outlier average was a 1.4% increase in fuel economy. Half of those increasing their fuel economy did so by only ~1%, while the other half improved by 4% to 9%, and later we look at this latter subgroup more closely to identify driving behaviors consistent with response to the feedback device. The bottom graph of Figure 3 shows the measured fuel economy of each participant with and without feedback (the data informing the top graph).

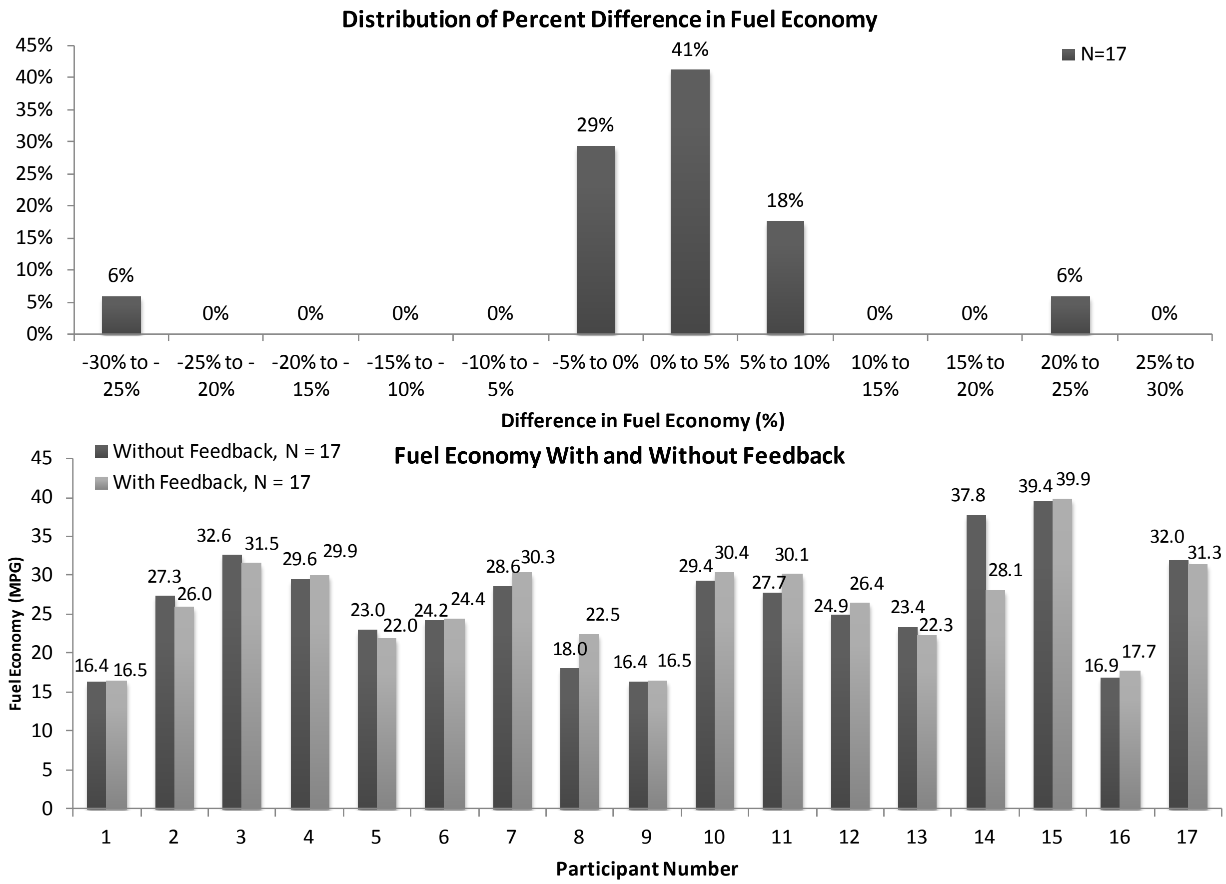

Figure 3 Fuel economy change and comparison with and without feedback.

Vehicle Operations Data

In addition to information on fuel consumption, the device collected more detailed information on a number of parameters of real-time vehicle operation at two-second intervals (on average). This data provided a far higher resolution of information for studying actual driving behavior, and was used to evaluate how drivers actually changed their behavior in response to the device. As indicated above, some drivers exhibited no change in behavior or improvement in fuel economy. These respondents may have chosen not to utilize the information, or did not find it effective for instructing them how to drive more efficiently. Other respondents did, and the two-second resolution of vehicle data illustrated changes in speed profiles can ascertain how drivers adjusted key behaviors.

Data from the device was processed to evaluate how drivers accelerated from a stop. The authors processed all of a participant's acceleration from a stopped position and tracked it for the first 25 seconds. The average speed at each second across all acceleration events was then used to generate two profiles for each participant, one without the feedback device, and one with it. These profiles were then compared to evaluate whether the device had any influence on the driving of respondents when accelerating from a stop. A reduced acceleration profile is reflective of more-efficient driving. Generally, those that exhibited that improvements in fuel economy where also those that collectively lowered their acceleration profiles most. Figure 4 illustrates this effect at a high-level by presenting the average acceleration profiles of drivers that improved their fuel economy by 4% or more (n = 5), as well as the rest of the sample (n = 12). The top graph of Figure 4 shows the average acceleration profile of these "improved by 4% or more" participants both with and without the feedback, while the bottom graph shows the average acceleration profiles of the rest of the sample.

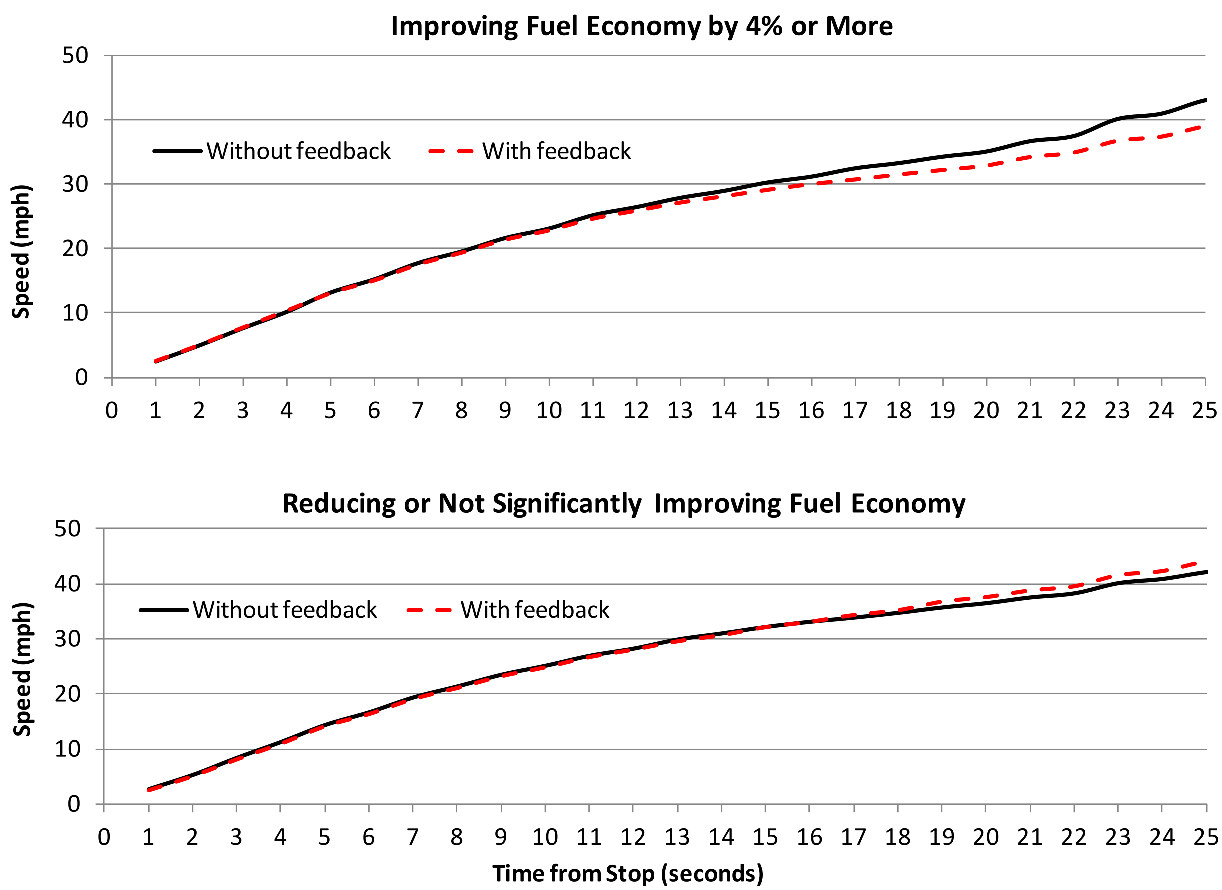

Figure 4 Average speed profile from vehicle stop.

In the top graph of Figure 4, the average speed profile with feedback is lower than without feedback. On the bottom graph, the average speed profile with and without feedback are nearly indistinguishable, with the "with feedback" profile actually rising above the "without feedback" profile at higher speeds and time away from vehicle stop. Notably, the average speed profiles for both the top and bottom graph are not different at lower speeds.

The vehicle operational data also found that some participants made shifts in how they decelerated to a stop. The operational data did find a distinction in the average speed profiles of those participants improving fuel economy by 4% or more, whereas the remaining subsample reflected little difference. As in Figure 4, Figure 5 illustrates the average deceleration profiles of the two subsamples.

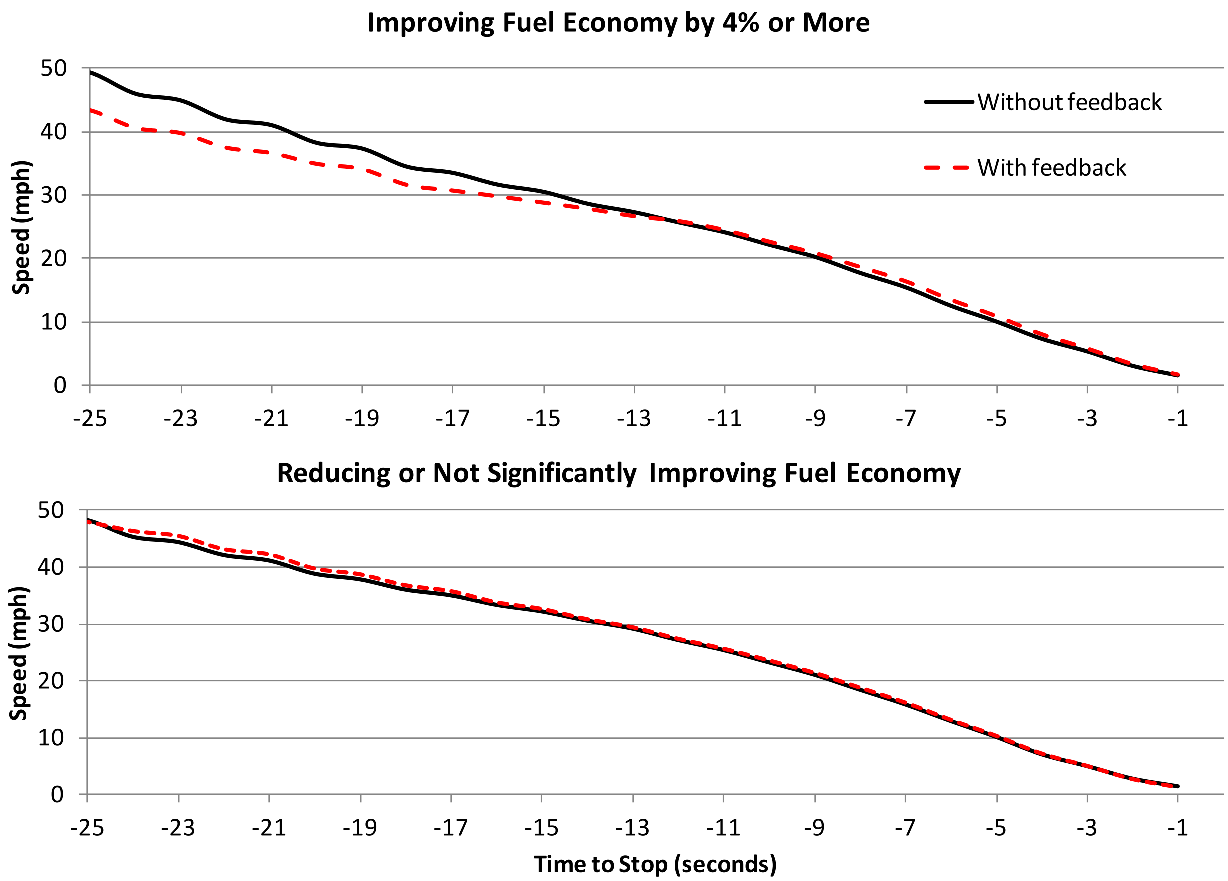

Figure 5 Speed profile to stop of vehicles that did and did not improve fuel economy.

In Figure 5, as in Figure 4, the top graph shows the greatest differences with and without feedback to be at the higher speeds preceding a stop. The bottom graph shows that those with little or no improvement in fuel economy exhibited very small distinctions in the average speed profiles generated with and without feedback. While Figures 4 and 5 show a distinction between these averages, it is important to note that some respondents in the "less-improved subsample" were found to alter the acceleration and deceleration profile as well. Across the entire sample, nine participants were observed to make some reduction to their acceleration from a stop, while eight were observed to make some reduction their deceleration profile. Most of these participants had increased their fuel economy marginally (~1%), but slight adjustments were observed in two participants that measured fuel economy reductions.

As indicated by the responses to the survey, the device also influenced the speed at which participants travelled on the highway. Driving above 55 to 60 mph (86 to 96 km/h) reduces fuel efficiency (*18*). Bay Area freeways generally have 65-mph (105-km/h) speed limits; thus, these optimal speeds are regularly exceeded. The faster a vehicle travels over this optimal speed range, the lower the fuel economy. The vehicle data shows that the feedback appeared to lower the average speed the respondents traveled on uncongested highways.

Figure 6 illustrates this effect through two distributions taken from observations of vehicle speed 55 mph and above. The top graph shows the cross sample distribution of all observations of speed at 55 mph and above. That is, they represent the number of 2-second observations of each speed. The bottom graph show the distribution of change in average highway speed (55 mph or greater). That is, any observations of speed below 55 mph were not included in the average, so as to only consider highway driving speeds.

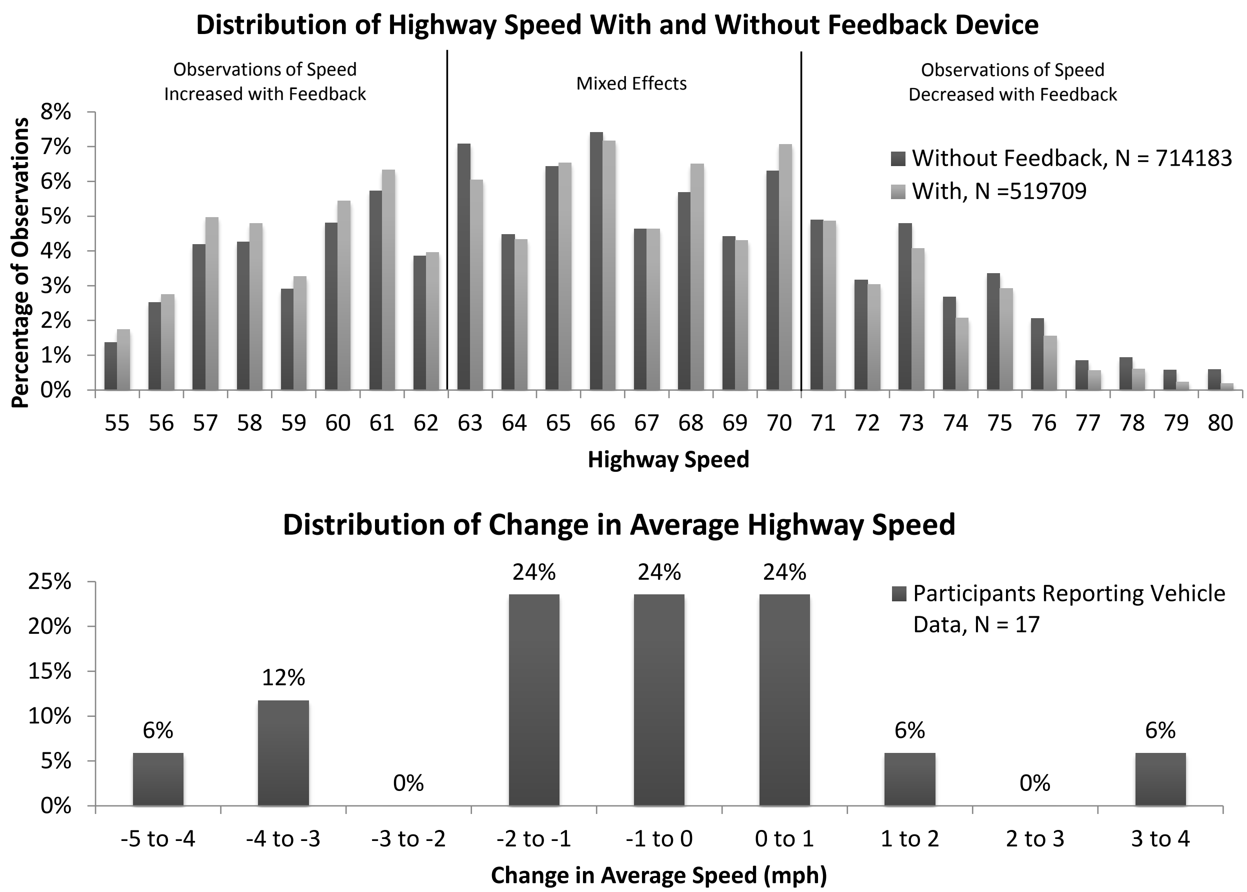

Figure 6 Change in Highway Speed Observed in Study Participants

The bottom of Figure 6 shows that the majority of participants (n = 11), exhibited a decline in their average highway speeds driven with the feedback, while the remaining six exhibited an increase in average highway speed. The overall sample exhibited a slight decline in average highway speed from 65.9 mph (106 km/h) to 65.4 mph (105 km/h). This change is slight, but evident in the reduction of observations of speeds above 70 mph (113 km/h), and an increase in the number of observations below 63 mph (101 km/h). Interestingly, a number of participants that did not exhibit notable increases in fuel economy (>4%), did exhibit a reduction in average highway speed. This suggests that uptake of specific ecodriving behaviors was likely varied across the sample. The feedback may have influenced some respondents to make changes that, while observable in certain dimensions, where not influential enough by themselves to make sizeable changes to their fuel economy.

CONCLUSION

The results from this study suggest that the real-time feedback of the device is influencing the driving behavior of some participants. It is clear from both the survey data and the vehicle operation data that the impact of real-time feedback is not universal. The survey data suggest that a majority of participants used the device to change how they drove in some way. But the vehicle data show that the device changed different behaviors in different people. Some participants reduced the speeds at which traveled when accelerating away from, or decelerating towards a stop. The vehicle data also showed that average highway speeds generally declined for a majority of the sample. These behaviors all improve fuel economy in isolation, but need to be applied in concert and consistently for appreciable improvements in fuel economy to be measureable.

Thus, the survey data in combination with the vehicle data suggest that the device is improving the fuel economy of some participants. But measuring the exact magnitude of that influence is difficult in an uncontrolled, real-world environment. While it is known that the behaviors observed by participants improve fuel economy, the degree to which behavioral change saved fuel is more difficult to isolate. Other factors, such as variations in passengers across the two months of participation, the mix between city and highway driving, and the changes in the contents of the trunk, can cause measured fuel economy to change in either direction. The combination of the vehicular data, which shows a direct change in behavior, and the survey data, which reports human response to the device, does suggest that the device provides enough information to alter driving behavior. The degree to which that information is used, was certainly found to vary across the sample.

These results reflect the impact of just one type of feedback, which is rather simple. Participants only saw information to about instantaneous fuel economy. With this information, the driver had to respond by self-teaching how to drive more efficiently. The ability or willingness of drivers to practice this instruction is naturally varied across the population with different effects. Other types of feedback, which are more instructional, are also possible, and might provide better results across a wider group of people. Devices with more complex algorithms could instruct drivers on how to accelerate based on measured pedal position, or when taking information from infrastructure (such as traffic signals), inform drivers of the speed necessary to maintain to cruise through signalized arterial. These innovations constitute the future of ecodriving interventions. Overall, the results projected here, as well as several previous studies do suggest that the simple provision of information can lead to changes in fuel consumption. Expanded incorporation of such technologies, particularly in non-hybrid vehicles, would still hold promise to yield fuel savings, even as more advanced approaches to feedback and instruction are developed.

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