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ABSTRACT

Ecodriving, the concept of changing driving behavior and vehicle maintenance to impact fuel consumption and greenhouse gas (GHG) emissions in existing vehicles, has gained recent prominence in North America. One ecodriving strategy involves public education through Internet-based information dissemination. This paper presents the results of a controlled stated-response study conducted from June to December 2010 with approximately 100 University of California, Berkeley faculty, staff, and students, assessing the effectiveness of static ecodriving web-based information. A comparison of the experimental and control groups found that exposure to ecodriving information influenced people's driving behavior and maintenance practices. The experimental group's distributional shift was statistically significant, particularly for key practices including: lower highway cruising speed, driving behavior adjustment, and proper tire inflation. Within the experimental group (N = 51), fewer respondents significantly changed their maintenance practices (16%) than the majority that altered some driving practices (71%); this suggests intentional altering of driving behavior is easier than planning better maintenance practices. A comparison of before-and-after surveys found that 57% of the experimental group improved their ecodriving behavior, while 43% made no change or worsened. Key characteristics of the drivers that improved include: being female, living in smaller households, and owning a newer car with higher fuel economy. While it was evident that not everyone modifies their behavior as a result of reviewing the website, even small shifts in behavior due to inexpensive information dissemination could be deemed cost effective in reducing fuel consumption and emissions.

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

WORD COUNT: 7,439 words, including 3 figures and 5 tables

INTRODUCTION

Concerns over unstable fuel prices, environmental protection, and energy security have prompted a renewed public and private interest in improving fuel economy. From the consumer perspective, the motivation to reduce fuel use is financial, as rising gasoline prices further constrain budgets in challenging economic times. From a social and political perspective, the motivation stems from energy dependence and climate change considerations. While investment in advanced technologies, fuels, and infrastructure offers long-term petroleum reductions, existing consumer actions to lower fuel consumption immediately are more limited.

Ecodriving, the concept of altering driving behavior and vehicle maintenance practices in the existing vehicle fleet, has gained recent prominence as a strategy for consumers to reduce gasoline consumption. Ecodriving is attractive as it is easily implementable regardless of the vehicle driven, and it has been reported to reduce fuel consumption between 10 to 20% (1). Consumers facing fixed transportation needs dependent on the automobile can take actions to

immediately reduce their fuel consumption. Ecodriving offers numerous benefits, including reduced fuel use and greenhouse gas (GHG) emissions, cost savings, greater safety and comfort, and less noise pollution.

Ecodriving practices are generally categorized into two areas: driving behavior and vehicle maintenance. Ecodriving interventions include static and dynamic interventions. Static approaches consist of general ecodriving information and techniques (e.g., brochure or website), which a driver can apply after learning. Dynamic ecodriving involves the use of in-vehicle devices that provide direct feedback to the driver while driving. Both interventions provide advantages. Dynamic ecodriving devices are more proactive and continuous in their feedback, while static ecodriving interventions are lower cost, providing the passive delivery of basic knowledge.

Public education through social marketing (i.e., marketing directed at promoting a social good through behavioral change) has the potential to change travel behavior to reduce GHG emissions. One outreach strategy currently practiced in the United States (U.S.) is Internet-based ecodriving information dissemination. This form of static intervention is a low-cost means to deliver information. The ecodriving adoption rate from a static intervention, however, is uncertain. In particular, key questions remain regarding which driving practices consumers are most likely to adopt and sustain from ecodriving information. A potential benefit of public education is that resulting behavioral changes, even if modest, could cost effectively reduce fuel use.

This study evaluates driver response to the website www.ecodrivingusa.com, developed by the Alliance of Automobile Manufacturers to educate the public on ecodriving. As a form of static intervention and public education, the website contains informational videos and descriptions on ecodriving practices. To evaluate the impact of this information on driving behavior, the authors conducted a longitudinal survey of drivers in the San Francisco Bay Area from June to December 2010. The drivers were divided equally into an experimental and control group, where the experimental group reviewed the *EcoDrivingUSA*™ website and the control group did not. In this paper, the authors review how the ecodriving information received by the experimental group altered drivers' stated behavior in comparison to the control group. The paper is organized into four sections. First, the authors discuss ecodriving public education and outreach programs in Europe, Asia, and North America and research on their effectiveness. Second, the study methodology is described, followed by an analysis of the survey data. Finally, the authors present conclusions and recommendations for future research.

LITERATURE REVIEW

Since ecodriving includes both driving and maintenance practices, there are many combinations of actions that individuals can take to improve driving efficiency. It is likely that most drivers actively engage in some practices without further prompting. Some of the key driving and maintenance practices listed on the *EcoDrivingUSA*™ website are (2):

- Avoid rapid starts and stops;
- Keep tires properly inflated;
- Use the air conditioner at speeds above 64 kilometers/hour (km/hr) (40 miles per hour (mph)) and open the windows below it;
- Maintain 97 km/h (60 mph) on the highway;
- Use the lowest weight motor oil to improve kinematic viscosity;

- Change air filters, as recommended by the manufacturer;
- Accelerate smoothly and coast to stops and parking spots;
- Do not idle a vehicle or warm up the engine;
- Avoid unnecessary weight;
- Remove roof racks; and
- Tighten the gas cap to prevent evaporative losses.

Recognizing the potential of ecodriving to save money and reduce fuel use and emissions, many ecodriving campaigns have been launched to educate and train individuals to drive more economically and efficiently. The methods used for education vary among countries but typically involve outreach, education, and training components. The authors focus on public education and awareness programs, with less discussion on behind-the-wheel training, feedback technologies, and fleet applications. The majority of existing education programs are located in Europe, with fewer programs in Asia and North America.

Europe

Ecodriving research into education program effectiveness has been predominantly based on longitudinal driving trials. In 2002, a Dutch research team studied the effects of following Dutch ecodriving tips on fuel consumption and emissions. The study indicates that ecodriving techniques can reduce fuel consumption by 7 to 10%, depending on vehicle type (diesel or petrol) (3). A similar Belgian study showed that savings from 5 to 25% could be achieved by following Dutch ecodriving guidelines (4).

On a larger scale, several pan-European ecodriving campaigns have been launched over the past decade. "*ECO-DRIVING EUROPE*" began in 2001; it was sponsored by the Austrian Energy Agency to build a network and understanding of ecodriving across Europe (5). In 2006, Intelligent Energy Europe (IEE) started a more extensive project, "*ECODRIVEN*," which operated from January 2006 to December 2008, in nine countries in the European Union (E.U.); it reached more than 20 million drivers (6, 7). Another pan-European project supported by IEE was the "*Treatise project*," which ran from January 2005 to June 2007. This project provided free training on various sustainability topics for energy and transport professionals. Treatise trained 1,722 people on the topics of cleaner fuels and vehicles, ecodriving, and mobility management. It initiated 41 local transport projects, resulting in 95 kilotonnes (kt) of carbon dioxide (CO_2) savings (8). More recently, "*eCoMove*" was launched in 2010, as a three-year program funded by the European Commission with over 30 consortium partners. *eCoMove* attempted to reduce fuel use by providing more efficient route choice, driving performance, and traffic management and control by providing information and communication technologies (or ICT) to drivers, fleet managers, and traffic managers (9).

These programs have supported national ecodriving campaigns, such as *Het Nieuwe Rijden*, or "*The New Ride*," in the Netherlands. Beginning in 1999 and following the Kyoto Protocol targets, the campaign had goals to reduce CO_2 emissions by 0.8 kt annually by 2010 (i.e., a 2.4% emission reduction due to road transport) (*10*). There were five target areas: 1) driving school curricula, 2) re-education of licensed drivers, 3) fuel saving in-car devices, 4) tire pressure, and 5) consumer behavior. The program owed much of its success to its extensive partnerships with public and private institutions, as well as its advertising campaign, which focused on immediate individual benefits, such as cost savings and comfort rather than the environment. In its 2007 annual evaluation, results showed that 80% of drivers were familiar

with the campaign, 90% of driving instructors were trained in ecodriving, one third of drivers applied ecodriving techniques, and at least 0.3 million metric tons (Mt) of CO_2 emissions were avoided due to the program (*10*).

Asia-Pacific

Most public education programs in the Asia-Pacific are in Japan and Australia. Ecodriving research and campaigns in Japan have focused on driving trials, simulation modeling, and monitoring devices. One public education website, www.ecodrive.jp, provides ecodriving tips to viewers and serves as a portal to other informational websites (*11*). In an early effort in Australia, Syme et al. (1987) conducted a study evaluating the effects of a television campaign encouraging viewers to conserve petroleum by implementing ecodriving practices. The researchers evaluated the effect of two different campaigns: one emphasized saving money and the second good citizenship. Regardless of theme, both campaigns had a small but statistically significant effect on attitudes and beliefs, intention to save petroleum in the future, and self-reported conservation behaviors (*12*). There are a few Australian ecodriving public education programs today, which could be due to a lack of quantitative data from the Australian driver context and a focus on commercial fleets (*13*, *14*). In 2001, the Victorian Environmental Protection Authority and Sustainable Energy Authority Victoria developed a one-day training program on the environmental and safety implications of driving habits; however, there were no studies of its impacts (*13*).

North America

Canada began a nationwide ecodriving initiative in 2007, which is led by the ecoENERGY program. The ecoENERGY for Personal Vehicles Initiative provides a variety of teaching tools, online resources, publications, and driver tips. The educational program, "*FleetSmart*," focuses on ecodriving for trucks and buses and is sponsored by ecoENERGY for Fleets (*15*).

Ecodriving initiatives began more recently in the U.S. The Alliance of Automobile Manufacturers launched *EcoDrivingUSA*™ (www.EcoDrivingUSA.com) in August 2008—a nationwide effort to increase fuel savings, while reducing fuel consumption and emissions that was supported by 18 states and territories (2). The authors employed the *EcoDrivingUSA*™ website and printed materials in this study. The Alliance has discontinued its ecodriving campaign efforts, at present, due to budgetary cuts (*16*). Several state departments of transportation also started ecodriving campaigns. The North Carolina Department of Transportation (NCDOT) began "*Drive Green, Save Green*" in April 2010, with a website containing tips and instructional videos (*17*). The I-95 Corridor Coalition began its campaign "*Eco-Driving: Drive Green, Save Green"* in May 2011, modeled after the similarly named NCDOT program (*18*). A recent study by Boriboomsomsin et al. (2011) assessed ecodriving public awareness in Southern California, as part of a broader study on real-time feedback effectiveness. This study found that the sample knew about ecodriving practices on a "moderate" level, but they did not implement their knowledge (*19*).

Ecodriving outreach efforts have the potential to impact driving behavior. However, there is little research evaluating behavioral changes resulting from ecodriving information alone. In this paper, the authors advance this understanding by evaluating the degree to which drivers change their behavior in response to static information conveyed on a website.

METHODOLOGY

The authors designed a controlled study in which respondents were divided equally into an experimental and control group. Both groups then participated in a longitudinal study as described below.

Longitudinal Survey

The research team conducted recruitment and data collection for the longitudinal study from June to December 2010. Participants were chosen among University of California, Berkeley faculty, staff, and students who volunteered to participate. Participants were given a $15 gift card for completion of the two to three surveys (depending on assigned group). In total, 162 people began the survey of whom 104 completed the entire study. The final sample was comprised of two subsamples: 51 experimental and 53 control.

Researchers developed and pretested a before-and-after survey that participants completed online over a three-month period. In the "before" survey, researchers asked 62 questions to assess current driving and vehicle maintenance practices. The authors used these data to establish a comparative baseline. Researchers also asked attitudinal questions to capture demographics, existing vehicle ownership, and climate change views. The participants were divided into two groups according to the order in which they joined the study. If the order of a participant joining was an odd number, the subject was assigned to the "experimental" group. If the participant joined as an even number, then he or she was assigned to the "control" group. Participants did not know which group they were in nor did they know that there was another group. Participants in both groups were directed to take the same "before" survey upon entering the study. The experimental group was then asked to visit the *EcoDrivingUSA*™ website during the upcoming week to introduce and provide more in-depth ecodriving information. The experimental group was sent a follow-up, 25-question survey regarding the ecodriving information conveyed on the website. The remaining participants were the study's control group; they were not shown the website and did not receive the treatment survey. Three months later, all participants were administered the "after" survey, which asked 62 questions concerning any changes in vehicle ownership, maintenance, and driving practices. Most of the questions in the "after" survey were comparable to the "before" survey to evaluate whether any behaviors had changed.

The objective of the study design was to evaluate the degree to which exposure to static ecodriving information would influence people's driving behavior and maintenance practices. While monetary incentives were included to draw a more general population, self-selection bias naturally existed among those that voluntarily joined the study. Among study participants, self-selection was controlled for by the research team, as the entire sample was unknowingly split into two groups to focus on the differential impact of exposure to static ecodriving information.

Study Limitations

There were several limitations that arose along the study's duration. Many of the survey questions relied upon stated response regarding behavioral change. This included questions that asked participants to self-assess their propensity to practice ecodriving techniques. The questions were tailored to explore comparative response changes, and the time between surveys was relatively long. Nevertheless, driving behavior could not be verified, as respondent vehicles were not equipped with telematics equipment. This study relies on respondent stated response. In addition, given some knowledge of the study purpose, self-assessment bias may have occurred in

how efficiently respondents actually drive. The scientific control design was intended to help correct for this, as all respondents had the same basic understanding of the study purpose.

LONGITUDINAL SURVEY RESULTS

The study results are divided into three sections. The first section presents the sample demographics. The second describes the effectiveness of the ecodriving information through a comparison of the experimental and control group. In the third section, the authors focus on specific responses of the experimental group to the ecodriving information.

Demographics

The survey demographics demonstrate that the control and experimental groups were broadly distributed across key characteristics. The sample size was 53 for the control group, and 51 for the experimental group. Since the study population was drawn from a university population, it is not reflective of the general population. This population was selected so researchers, based at the university, could cost effectively implement multiple recruitment methods (i.e., email, posters, class announcements) within the limited study budget. Both groups exhibited a diverse income distribution, with more than 20% of each sample earning more than $100,000 annually. The race distribution of the samples exhibited a Caucasian share reflective of the state population; however, Asians were over represented, and African-Americans and Hispanics were under represented. Other ethnic populations were relatively small, representing or over representing their state population shares. The education level of both samples is higher than the state average, but it is more reflective of the San Francisco Bay Area. Table 1 presents a summary of the key demographics of each survey group.

TABLE 1 Longitudinal Survey Demographics

2009 Household Income	*Control*	*Experimental*	**Race**	*Control*	*Experimental*
Less than $10,000	4 (8%)	1 (2%)	Caucasian	19 (36%)	25 (49%)
$10,000 to $15,000	2 (4%)	2 (4%)	Hispanic or Latino	1 (2%)	2 (4%)
$15,000 to $25,000	6 (11%)	4 (8%)	African-American	3 (6%)	2 (4%)
$25,000 to $35,000	6 (11%)	3 (6%)	Asian	17 (32%)	9 (18%)
$35,000 to $50,000	3 (6%)	5 (10%)	Native American or Alaskan Native	0 (0%)	1 (2%)
$50,000 to $75,000	4 (8%)	9 (18%)	Hawaiian or Pacific Islander	0 (0%)	2 (4%)
$75,000 to $100,000	8 (15%)	5 (10%)	Indian	2 (4%)	1 (2%)
$100,000 to $150,000	8 (15%)	10 (20%)	Arab or Middle-Eastern	2 (4%)	1 (2%)
$150,000 to $200,000	2 (4%)	0 (0%)	Mixed Race	2 (4%)	3 (6%)
More than $200,000	1 (2%)	5 (10%)	Decline to Respond	4 (8%)	3 (6%)
Decline to Respond	9 (17%)	7 (14%)	Other	2 (4%)	1 (2%)
Household Category	*Control*	*Experimental*	**Education**	*Control*	*Experimental*
Self only	8 (15%)	14 (27%)	Grade School	0 (0%)	0 (0%)
Self with spouse/partner	14 (26%)	11 (22%)	Graduated High School	2 (4%)	2 (4%)
Self with spouse/partner and child(ren)	9 (17%)	9 (18%)	Some college	10 (19%)	8 (16%)
Self with child(ren)	1 (2%)	1 (2%)	Associate's Degree	1 (2%)	0 (0%)
Self with roommate(s)	13 (25%)	9 (18%)	Bachelor's Degree	23 (43%)	19 (37%)
Other, please specify:	7 (13%)	7 (14%)	Master's Degree (MS, MA, MBA, etc)	11 (21%)	13 (25%)
			Juris Doctorate Degree (JD)	0 (0%)	0 (0%)
Gender	*Control*	*Experimental*	Doctorate Degree (PhD, EdD, etc.)	4 (8%)	7 (14%)
Male	26 (49%)	23 (45%)	Medical Degree (MD, etc.)	0 (0%)	0 (0%)
Female	27 (51%)	28 (55%)	Other	2 (4%)	2 (4%)
Total	53	51	Total	53	51

Before-and-After Response: Differences Between the Control and Experimental Group

The longitudinal survey probed respondent "self-perceived efficiency," as well as more specific changes in driving and maintenance behavior. These included questions regarding highway cruising speed, acceleration and braking behavior, and maintenance practices. The results

suggest that exposure to ecodriving information does influence some people's behavior. The presentation of static ecodriving information appeared to result in modified behavior in some individuals within the experimental group. These shifts occurred while overall behavioral shifts in the control group were generally absent. This provides some indication that ecodriving information can impact the behavior of a subset of drivers. However, the shifts observed were of moderate size and did not constitute a wholesale change in behavior among all participants in the experimental group. As with most any change in transportation behavior, there was a distribution of heterogeneous effects.

To illustrate this dynamic, Figure 1 presents the experimental and control group responses to the question: "When you drive on the highway in free-flow traffic (such as 101, 680, or 880), what cruising speed do you typically try to maintain?" The "before" (dark) and "after" (light) distributions of the experimental group are presented in the top graph, while the control group before-and after distributions are presented on the bottom graph. During the "before" survey, the mode of both the treatment and control group distributions was 70 mph (113 km/h). During the "after" survey, the experimental group distribution shifted such that the mode was 65 mph (105 km/h)—a more energy-efficient highway speed. However, the control group mode remained at 70 mph (113 km/h).

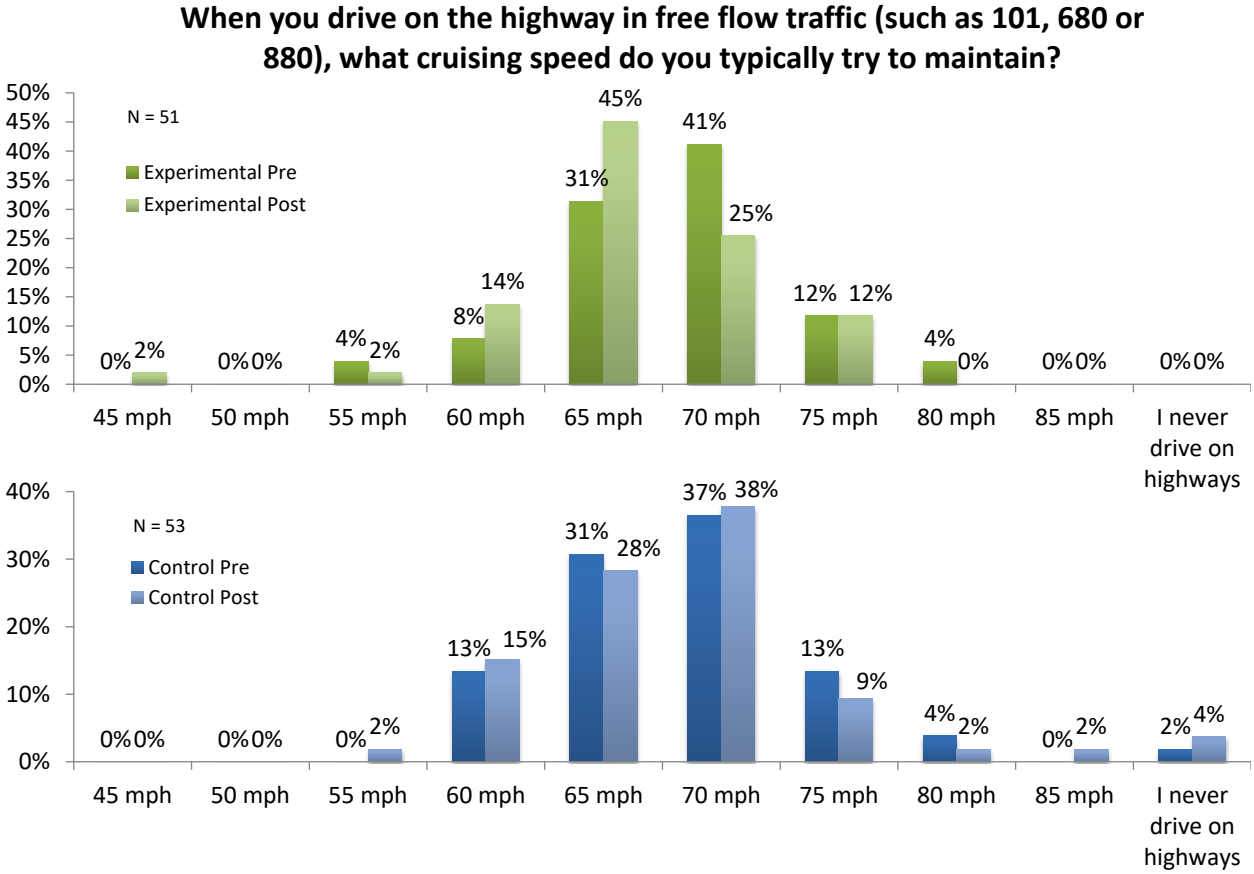

FIGURE 1 Shift in highway cruising speed.

Because the survey data were mostly ordinal in nature, the authors used non-parametric tests to evaluate the statistical significance of reported behavioral changes. This includes the

Wilcoxon signed-rank test for paired samples and later the Mann-Whitney test for cross-sectional comparisons. Many of the observed shifts in driving and maintenance behavior by the experimental group were statistically significant. Table 2 presents a summary of key survey questions, the responses available for each, and the comparative results of the Wilcoxon signed-rank test. For each of these questions, responses can shift upward or downward. In the case of Figure 1, the reported highway speeds shifted downward. Table 2 reports the significance of the one-tailed Wilcoxon signed-rank test to demonstrate the general direction of the distribution shift and whether the magnitude was large enough to be considered statistically significant. For example, if responses shifted more downwards than upwards (as they did in Figure 1), then the *p*-value for the one-tailed test of the downward shift was reported (the upward shift test value would equal to 1 minus the downward *p*-value). Related to Figure 1, Table 2 shows the results of the Wilcoxon signed-rank tests for highway cruising speed change. The shift in the experimental group's distribution is statistically significant ($p = 0.018$), while the shift in the control group's distribution is not significant ($p = 0.21$). The shift observed with other questions follow in Table 2.

TABLE 2 P-Values from Wilcoxon Signed-Rank Test

Question	Possible Responses	One-Tailed Test P-Value (shift direction)	
		Experimental	Control
When you drive on the highway in free flow traffic (such as 101, 680 or 880), what cruising speed do you typically try to maintain?	< 45 mph (downward-most response) 45 mph 50 mph 55 mph 60 mph 65 mph 70 mph 75 mph 80 mph 85 mph More than 85 mph I never drive on highways (upward-most response)	0.018† (downward)	0.21 (downward)
Overall, how well do you think that your car is maintained?	Not well at all Not very well Okay, but could be better Rather well Very well	0.029† (upward)	0.47 (downward)
How efficiently, in terms of fuel usage, do you think you drive your vehicle now?	Very inefficiently Somewhat inefficiently About average Somewhat efficiently Very efficiently	0.086* (upward)	0.27 (downward)
On cold mornings, how long do you typically warm up the car before starting your trip?	~0 seconds About 15 seconds About 30 seconds About 45 seconds About 1 minute About 1.5 minutes About 2 minutes More than 2 minutes	0.037† (downward)	0.001† (upward)
When driving your primary vehicle, how often do you adjust your driving behavior in ways to improve your fuel economy?	Never Rarely Sometimes Often Always	0.00076† (upward)	0.34 (upward)
I regularly use the manufacturer recommended motor oil.	Strongly Disagree Disagree Agree Strongly Agree	0.51 (upward)	0.36 (upward)
I regularly check and properly inflate my tires at least once a month.	Strongly Disagree Disagree Agree Strongly Agree	0.0084† (upward)	0.048† (upward)

*statistically significant at the 10% level †statistically significant at the 5% level

The shift in before-and-after survey responses suggest that a subset of the experimental group receiving ecodriving information made a cognizant effort to adjust their driving in ways to improve efficiency in contrast to the control group. Furthermore, the number of respondents making a shift was large enough to be statistically significant at the 5 or 10% level in most cases. As all impacts are of a distribution, there inevitably existed some experimental group members that did not modify their stated behavior. However, in contrast to the control group, experimental group respondents made an effort to alter their driving and vehicle maintenance in ways that they would not have in the absence of the study information. Table 2 shows that respondents in the experimental group exhibited a statistically significant shift towards believing that their car was better maintained ($p = 0.029$), driving more efficiently ($p = 0.086$), and adjusting their driving behavior to improve fuel economy ($p < 0.001$). In these three cases, the distribution of the control group responses did not change markedly. Table 2 also shows that respondents reduced the time that they would warm up a vehicle ($p = 0.037$), whereas the control group exhibited a significant shift towards waiting longer before driving ($p = 0.001$). In the case of the bottom two Likert-scale questions pertaining to maintenance, neither group reported shifts in their motor oil use, while both groups increased the degree to which they checked and inflated their tires.

Behavioral Changes Within the Experimental Group

Overall, the comparative response shift between the experimental and control group strongly suggests that providing ecodriving information through the EcodrivingUSA™ website did induce the experimental group to shift behavior more than they would have otherwise. It is important to emphasize that this shift reflects a distribution of effects and is driven by a subset of people who did adopt behavioral changes. To explore this dynamic further, this section probes the experimental group responses to ascertain key qualities of those that adopted behavioral changes and which specific behaviors were altered.

Self-Assessment of Driving and Maintenance Changes

Respondents in the experimental group post-survey were asked directly whether they changed their driving behavior and maintenance practices as a result of reviewing the website. Respondents were first asked whether they had made driving behavior changes. Those that answered “Yes” were then asked whether they had changed their behavior *due to* what they learned on the EcoDrivingUSA™ website. Those that answered “Yes” to this second question were asked to identify which practices they adjusted. The same pattern of question was asked regarding maintenance practices, and the summary of both is presented in Table 3.

TABLE 3 Experimental Group "After" Survey Questions about Changes in Driving and Maintenance Behavior

Have you made changes in your driving behavior to improve fuel economy since starting the study?			***During the past 3 months, did you change anything about how you drove (e.g., your driving style) because of what you learned from the ecodrivingusa.com website?***		
Yes	36	71%	Yes	33	92%
			No, I changed the way I drive for other reasons	3	8%
			No, I still drive about the same as I did 3 months ago	0	0%
No	14	27%	Total	36	100%
I don't know	1	2%			
Total	51	100%			

What driving practices did you change during the study? (please check all that apply)	**Count**	**Percent**
None	0	0%
I accelerate more gradually	33	100%
I brake more gradually	26	79%
I idle my car less	11	33%
I drive closer to 60 mph on the highway	15	45%
I change how and when I use the air conditioner	18	55%
I consider using cruise control more often	9	27%
I got a FasTrak	6	18%
I already did all of these things	0	0%
I changed other practices, please explain:	0	0%
Total	33	100%

Do you think that your vehicle maintenance has improved over the last three months?			***Do you think that your vehicle maintenance has improved because of what you learned from the ecodrivingusa.com website?***		
Yes, it's better	8	16%	Yes	7	88%
			No, my vehicle maintenance improved for other reasons	1	13%
No, it's about the same	42	82%	Total	8	100%
No, it's worse	1	2%			
Total	51	100%			

What maintenance practices did you improve during the study? (please check all that apply)	**Count**	**Percent**
I changed the motor oil more frequently	5	71%
I have checked to ensure that the proper motor oil is used	1	14%
I checked my tire pressure more frequently	6	86%
I placed a tire gauge in my car, where there was not one before	1	14%
I got my vehicle engine inspected	1	14%
I got my air filter inspected	2	29%
I removed excess material out of my trunk or cargo area	3	43%
I bought fuel efficient tires	1	14%
I tighten my gas cap more conscientiously	2	29%
I removed a luggage rack or bike rack from my vehicle	0	0%
I got my vehicle air conditioning inspected	1	14%
I read my vehicle's owner's manual	1	14%
I was already doing all of these things	0	0%
Other, please explain	0	0%
Total	7	100%

The results shown in Table 3 illustrate that the experimental group respondents were much less responsive to altering their vehicle maintenance practices. Only seven attributed vehicle maintenance changes to the website, most of whom changed the oil and checked tire pressure more frequently. Thus, the number of experimental group respondents engaged in meaningful changes in their maintenance practice was far smaller than the majority who altered some driving practices.

Ecodriving Score

To evaluate how respondents in the experimental group shifted as individuals, respondents were each given two "ecodriving scores"—one for the "before" survey and one for the "after" survey—based on 12 survey questions that assessed their knowledge and practice of ecodriving principles (e.g., acceleration and braking patterns, frequency of driving behavior adjustment, highway cruising speed, and vehicle aerodynamics). A threshold was also established, whereby respondents were grouped into two categories for each survey: "ecodriving" versus "not ecodriving." While there is no definitive threshold, the authors defined a score of 60% as descriptive of general ecodriving practice responsiveness. Figure 2 presents a matrix of the respondent scores from the before-and-after survey. The matrix is divided into four quadrants by dotted lines and by three shaded regions. Respondents in Quadrant IV scored above 60% for both the before-and-after surveys. Quadrant II defines those below the 60% threshold for both surveys, and the opposite quadrants show respondents that scored above the threshold in one survey and below it in the other. The totals of each quadrant are indicated in the subtable below.

The areas separated by shaded regions indicate relative improvement. Even if respondents did not pass the (somewhat arbitrary) 60% threshold, those 29 within the upper right triangle improved between surveys, while the lower left triangle shows the six who worsened; 16 in the light gray region remained unchanged. Those respondents that improved (regardless of score) are analyzed in the next section.

Ecodriving Score

After / Before	0 - 10%	10 - 20%	20 - 30%	30 - 40%	40 - 50%	50 - 60%	60 - 70%	70 - 80%	80 - 90%	90 - 100%
0 - 10%	II									I
10 - 20%					1	1				
20 - 30%				1						
30 - 40%			1	1		2	2	1		
40 - 50%				1	8	6	4	2		
50 - 60%				1	1	2	2	1	1	
60 - 70%						1	4	5		
70 - 80%							1	1		
80 - 90%										
90 - 100%	III									IV

Quadrant and Classification	Total	Improvement Category	Total
Quadrant I (Ecodriving not before, but after)	13	Improved ecodriving	29
Quadrant II (Not ecodriving before or after)	26	Stayed the same	16
Quadrant III (Ecodriving before, but not after)	1	Reduced ecodriving	6
Quadrant IV (Ecodriving before and after)	11		

FIGURE 2 Distribution of ecodriving scores.

Demographic, Attitudinal, and Vehicular Characteristics of Improved Drivers

In Figure 2, the authors divide the experimental group into "improved" and "non-improved" subsamples. Figure 3 presents key distributional differences between those that improved. Distributions of each group's demographics and usage of the EcoDrivingUSA™ website reveal several interesting findings. Demographic distributions show that improved drivers tended to be slightly older, more educated, and wealthier—all of which are typically correlated. A characteristic found to be statistically significant ($p = 0.046$, using a two-sample t test assuming unequal variances) was gender—improved drivers tended to be female, accounting for 65% of the respondents in this category. Difference in mean household size was significant at the 10% level ($p = 0.074$), with improved drivers living in smaller households averaging 2.6 persons. With regards to respondent attitudes, improved drivers tended to have slightly higher fuel cost concerns, as well as stronger beliefs in climate change and the severity of anthropogenic contributions.

The survey solicited the make, model, and vehicle year most driven by the respondent. Interestingly, the improved subsample had newer autos than their cohorts who did not improve, with mean vehicle ages differing significantly (6.7 years vs. 11.6 years, $p = 0.0020$). Lastly, the difference in mean vehicle fuel economy was also significant ($p = 0.0087$)—improved drivers' vehicles had higher fuel economy, averaging 27 mpg (8.7 Liters (L)/100 km), while non-improved drivers' vehicles averaged 23 mpg (10 L/100 km).

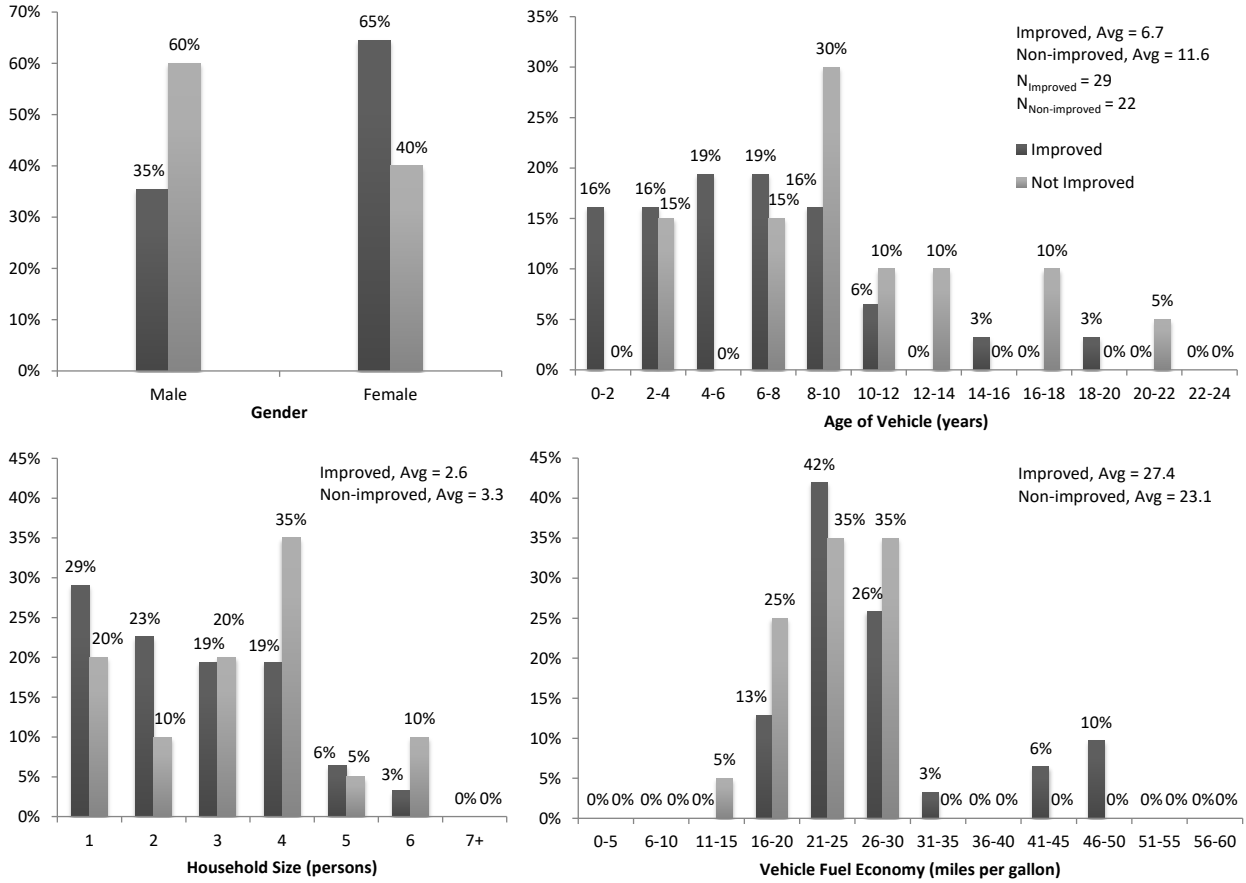

FIGURE 3 Distributions of key respondent characteristics by ecodriving improvement groups.

Website Effectiveness

Respondents were asked to visit the EcoDrivingUSA™ website and view key information and features that were deemed interesting, but they were not required to visit the entire website. To evaluate which information was perceived as most useful to the experimental group after they viewed the EcoDrivingUSA™ website, all respondents in the experimental group were given a survey to gauge their reaction to the website itself.

The first question sought to understand which features of the site they reviewed. Researchers sought to ascertain which of these components were most effective in *motivating* and *informing* respondents about ecodriving through a series of follow-up questions. The results of these three questions are summarized in Table 4, which shows that the video on the front page was one of most visited components of the site and most effective mediums for conveying information. The other highly visited and informative feature was the list of driving tips. Interestingly, nearly 90% of respondents saw the list of maintenance tips, but only about 10% thought that they were effective in motivating or informing them about ecodriving.

TABLE 4 EcoDrivingUSA™ Website Features Visited and Deemed Most Effective

What sections of the website did you visit? (Please check all that apply)			*Which section of the website did you find to be the most effective in informing you **about the reasons and incentives for eco-driving?** (choose one response)*		*Which section of the website did you find to be the most effective in **informing you on how to eco-drive?** (choose one response)*	
Website Feature	Count	%	Count	%	Count	%
The introductory video	37	74%	20	40%	15	30%
The list of maintenance tips	44	88%	6	12%	5	10%
The list of driving tips	47	94%	18	36%	25	50%
The quiz (Beginner)	14	28%	2	4%	1	2%
The quiz (Intermediate)	7	14%	3	6%	1	2%
The quiz (Pro)	3	6%	0	0%	0	0%
The endorsement of eco-driving by selected state governors	9	18%	0	0%	0	0%
The eco-driving game	14	28%	0	0%	0	0%
Other, please specify:	0	0%	0	0%	0	0%
None	0	0%	1	2%	2	4%
Total	50	100%	50	0%	49	0%

The survey further probed respondents on what maintenance practices they did not know prior to reviewing the website. Responses for both the improved and non-improved subsamples suggest that there are a number of facts about car maintenance that were unknown. These included facts about gas cap tightening, air conditioner maintenance, and fuel-efficient tires. In addition, the impacts of temperature swings on tire pressure and choice of motor oil on fuel economy were also indicated to be new information to a sizable respondent share.

While the "after" survey results from Table 3 show that most respondents did not engage in considerable maintenance behavioral changes, they were asked during the "after" survey whether they would engage in some of the practices suggested. Table 5 presents a summary of how responses were distributed. Two-thirds of respondents said that they would consider checking their vehicle tire pressure monthly. Other maintenance practices were also considered at levels not observed in practice, which suggests that undertaking proactive maintenance practices are among the more difficult ecodriving tasks.

Table 5 also presents a similar question for driving activities. Not surprisingly, the stated willingness to consider the list of ecodriving practices was higher and more aligned with the proportions of actual driving practices considered by the experimental group. This reinforces the conclusion that most of the improvements resulting from the ecodriving information were in the area of driving behavior versus vehicle maintenance changes.

TABLE 5 Driving and Maintenance Practices Most Likely to Be Considered

Based on the information that you saw at this site, what types of ***maintenance practices do you think you might give more consideration to over the next three months?*** *(Please check all that apply)*	Improved	Non-improved	Total
Change the motor oil more frequently	8 (16%)	2 (4%)	10 (20%)
Ensure the proper motor oil is used	6 (12%)	5 (10%)	11 (22%)
Check my tire pressure on a monthly basis	20 (40%)	13 (26%)	33 (66%)
Buy a tire gauge and keep it in my car	7 (14%)	7 (14%)	14 (28%)
Get my vehicle engine inspected	8 (16%)	2 (4%)	10 (20%)
Get my air filter inspected	14 (28%)	4 (8%)	18 (36%)
Keep excess material out of my trunk	12 (24%)	7 (14%)	19 (38%)
Consider fuel efficient tires for my next tire purchase	14 (28%)	8 (16%)	22 (44%)
Make sure my gas cap is tight	10 (20%)	6 (12%)	16 (32%)
Remove a luggage rack or bike rack from my vehicle	0 (0%)	0 (0%)	0 (0%)
Get my vehicle air conditioning inspected	9 (18%)	2 (4%)	11 (22%)
I will read my vehicle's owner's manual	10 (20%)	4 (8%)	14 (28%)
I already do all of these things	1 (2%)	2 (4%)	3 (6%)
None of the above	0 (0%)	0 (0%)	0 (0%)
Total	50	50	50

Based on the information that you saw at this site, what types of ***driving practices do you think you will consider over the next three months?*** *(Please check all that apply)*	Improved	Non-improved	Total
I will accelerate more gradually	19 (38%)	11 (22%)	30 (60%)
I will brake more gradually	16 (32%)	7 (14%)	23 (46%)
I will drive my car to warm it up	7 (14%)	6 (12%)	13 (26%)
I will drive closer to 60 mph on the highway	14 (28%)	7 (14%)	21 (42%)
I will change how and when I use the air conditioner	17 (34%)	6 (12%)	23 (46%)
I will use cruise control more often	12 (24%)	4 (8%)	16 (32%)
I will get a FasTrak	5 (10%)	1 (2%)	6 (12%)
I already do all of these things	1 (2%)	2 (4%)	3 (6%)
None of the above	0 (0%)	2 (4%)	2 (4%)
Total	50	50	50

CONCLUSION

This study assessed the effectiveness of education provided by the EcodrivingUSA™ website between June to December 2010. Based on the longitudinal results of approximately 100 respondents from the University of California, Berkeley, the comparison between the control and experimental group suggests that providing ecodriving information does influence the behavior of some drivers. The reported shifts are statistically significant and evidence of improvement in some drivers is shown from multiple angles in the data. It is clear, however, that not everyone modifies their behavior as a result of static ecodriving information, and some may only do so in small ways. Respondents who received ecodriving information did alter their behavior in several ways including: reducing highway speeds and vehicle idling, as well as accelerating and braking more gradually. Overall, 57% of experimental group respondents increased their ecodriving

score. In comparison to the rest of the sample, they were more likely to be female, drive a newer, more-efficient vehicle, and live in a smaller household. Respondents more often changed driver behaviors versus maintenance practices as a result of the ecodriving information. The resulting emission reductions, while relatively low in magnitude, are derived from an inexpensive intervention and thus more cost efficiently achieved.

Future ecodriving research offers opportunities to explore numerous types of interventions both independent of and in complement to the static ecodriving intervention analyzed in this study. Emerging research is evaluating dynamic interventions that provide real-time, in-vehicle feedback that coach the driver over time. Such technologies could offer considerable improvements that could be sustained over a longer time period. This study suggests that static ecodriving interventions could play an important role. In concert, dynamic and static interventions could provide greater fuel economy improvements and emission reductions that could be sustained over longer time frames.

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