Eco-driving Incentives in the North American Market

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ABSTRACT

Finding the correct incentives that will nudge drivers to improve their fuel efficiency is the key for achieving long-term change in their driving behavior. In this paper we discuss a participant study which is designed to provide insights on driver attitudes, behaviors and habits. This study focuses on residents in the San Francisco Bay area, and analyzes the eco-topic from multiple perspectives such as people's everyday routine, purchasing decisions, and driving habits.

The results show how income, age and gender of participants relate to their eco-friendliness. The most preferred types of information as well as visualizations for displaying fuel consumption and efficiency information in the car are discussed. Lastly, appropriate reward types for eco-driving are ranked and show what participants prefer best. The methodology and results of this research contribute to the design of automotive interfaces that may help people change their behavior and improve their fuel efficiency.

Categories and Subject Descriptors

H 5.2 [Information Systems]: Information interfaces and presentation – user interfaces, evaluation/methodology, graphical user interfaces (GUI)

General Terms

Design, Economics, Experimentation, Human Factors.

Keywords

Eco-friendly, Eco-driving, Energy efficiency, Automotive user interfaces, User interfaces, Long term behavior change, Original Equipment Manufacturer (OEM), North American Region (NAR).

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1. INTRODUCTION

Consumers need to be aware and educated in order to make conscious decisions when it comes to purchasing and using products or services, while at the same time considering the environmental consequences. People who are environmentally conscious usually belong to one of two schools of thought: either they are mostly concerned about energy efficiency from an environmental perspective, or they are concerned with their country's foreign dependence of energy and oil. Froehlich et al. [8] has discussed how environmental psychology can be linked to the design and evaluation of eco-feedback systems by basing the design of the system on the *responsible environmental behavior* or the *rational-economic* proenvironmental models. Even though the two perspectives are fundamentally different, both causes can be promoted by increasing energy efficiency and reducing fuel consumption.

When it comes to the automotive industry, OEMs have been making advances in modern vehicles that can achieve improved mileage with new innovative technologies. Nevertheless, a large part of the fuel consumption is dependent on the driver's driving behavior. As presented in the published research of the National Renewable Energy Laboratory by Gonder et al. [9], unless the driver acts responsibly during real-time driving and also adapts longer-term behavior, little improvement can be achieved.

There are currently numerous solutions offered on the market both by automotive manufacturers as well as aftermarket product suppliers, which aim to help the driver adjust his habits responsibly and improve energy efficiency. For example, Fiat, in collaboration with Microsoft, has developed a software feature called Ecodrive, wherein drivers can collect driving performance data from their car onto a USB stick, and then view and analyze their results on a computer [1, 6]. Smart USA Distributor company planted a tree for every Smart Fortwo sold in the USA in 2008, to show their support towards the environment [14]. GPS technology provider Garmin offers a feature called ecoRoute HD on their new portable navigation system which connects to the car and shows real time driving data on the device's screen [4]. The smart phone industry also offers numerous tools such as the Carticipate app for the iPhone [2], which allows users to coordinate their ridesharing group formation on the go. Lastly, government bodies are also actively supporting the environment. For example, the state of California offers tax credits of up to $3,150 savings for purchasing a Hybrid car or SUV [5].

Given the number and diversity of eco-incentives and solutions currently available to consumers today, it is important that in-car interfaces progress accordingly.

Published research indicates that providing feedback and designing appropriate incentives for consumers can have an influence on their decisions and behavior. Pace et al. [13] showed how giving real time feedback to drivers about their driving behavior has a positive effect on driving and can help them decrease fuel emissions. Also, on a topic that does not concern driving, Consolvo et al. [3] showed how providing participants with feedback in the Ubifit portable device, acts as a subtle but persistent reminder of being physically active, and has a positive effect on participants' persistence to exercise. UbiGreen [7], which is a project related to UbiFit, is a phone-based application that provides personal awareness about green transportation behaviors through iconic feedback. Froehlich et al. [7] showed how UbiGreen too can positively influence people's transportation decisions by providing appropriate feedback.

The goal of this study is to investigate the appropriate cues, information and incentives that will help drivers improve their energy efficiency in driving. The material is designed to gather the participants' perceived preference on different types of information, information visualizations as well as incentives for energy efficient driving.

2. EXPERIMENT DESIGN

This interview-based experiment was designed to provide insights into driver behavior and preferences. The study consisted of six subparts, each of which focused on a different aspect of being green and eco-friendly. It included questionnaires, cardsorting activities as well as rating and ranking exercises.

2.1 Participants

Forty adults (19 male and 21 female) between the ages of 19 and 63 years old were recruited from the local community to participate in the study. To ensure that the participants represent the North American region profile we recruited participants who have lived in the USA for at least the last 5 years. The participant pool consisted of adults holding a valid driver's license while 39 out of 40 owned their own car. Only one participant in the pool drove a hybrid electric car, while the rest of the 38 participants who owned a car drove regular combustion engine vehicles. The topic of the study was not revealed during recruitment because their attitudes and beliefs towards "eco-driving" might affect their decision to participate. Each experiment session lasted approximately 1 hour, and participants were compensated with a payment of $30 for their participation.

2.2 Apparatus and procedure

Experiment sessions took place in an interview conference room. Participants took part in the session and completed the activities on an individual basis. The whole study consisted of the following six parts, carried out in the order they are presented below.

2.2.1 Part 1: General background questionnaire

This paper-based questionnaire was used to collect general information from each participant, such as demographic information and driving experience. The questionnaire consisted of 16 questions.

2.2.2 Part 2: Eco-questionnaire

The Eco-questionnaire was used as the basis to assess the "eco-friendliness" of our participants. This questionnaire consisted of 40 questions and was split in the following sections:

i. **Energy efficiency perspective**. We asked participants the following question, in order to classify people into different groups. This question targeted the participants' general concern about energy efficiency and not their perspective on eco-driving specifically.
"My concern about energy efficiency is primarily:"
   a) *from an environmental perspective*
   b) *from an energy and oil dependency perspective*
   c) *from both a. and b.*
   d) *I don't really have concerns about energy efficiency*

ii. **Behavior towards the environment.** This part included 20 questions about people's daily habits related to recycling, gardening, energy usage at home, and transportation preferences.

iii. **Open-ended questions about awareness of eco-topics.** Participants were asked to respond on their awareness, concern and opinion on topics such as Global Warming, Foreign Oil Dependence, Kyoto Protocol, etc.

iv. **Purchasing decisions**. A list of products, such as food, cleaning supplies, and paper products, was presented to participants to assess purchasing preference for green/energy efficient alternatives compared to regular products.

v. **Comparison of regular and green/energy efficient products**. Participants were asked to rate green/energy efficient products compared to regular products based on 10 product characteristics. These included:
   - Environmental consequences
   - Exterior appearance
   - Fun of use
   - Safety
   - Social acceptance

Participant responses were analyzed with a scoring system which was developed by a group of experts. The experiment designers consulted with experts in psychology and researchers working on environmentally friendly behavior, for advice on weighing the score of the questionnaire's sections and questions. This information was used to determine each participant's Eco-score. The maximum amounts of points a participant could achieve was 118, and the results ranged from 50 to 103 points. Aggregate results from this questionnaire, such as energy efficiency perspective or recycling habits, were not used to draw results on the participants' average eco-friendliness. Instead these results were used only in relation to the responses of each participant in the rest of the experiment.

2.2.3 Part 3: Cardsorting with driving efficiency information

Participants were asked to perform two cardsorting exercises. Cardsorting is a technique employed to assess how people group concepts [12, 15]. Index cards are used to represent different information items and participants are asked to physically organize the pile of cards on a table. This technique can also be used for completing ranking exercises.

The decision to conduct two individual cardsorting exercises is key to the study. As discussed by Holmes [10, p. 155], “Eco-visualization is an interdisciplinary topic. To create a visual display (…) the author must synthesize knowledge and ask questions from four different arenas of research: responsive architecture, media art, information visualization, and sustainable design”. In order to remove any bias from the specific car system or portable device, the information and visual representation were decoupled and presented individually to participants. By splitting those two elements this experiment takes Holmes’ breakdown of Eco-visualizations one step further.

For the first cardsorting exercise participants were presented with different types of information a car or portable device in the car could give them about their driving efficiency. The list consisted of 16 different types of information, such as Fuel economy (MPG), Carbon footprint (CO_2lb/mi) and Idle time (sec). Each information item was printed on an index card with a label, measuring unit, and a short description of the information type, as shown in Figure 1 below.

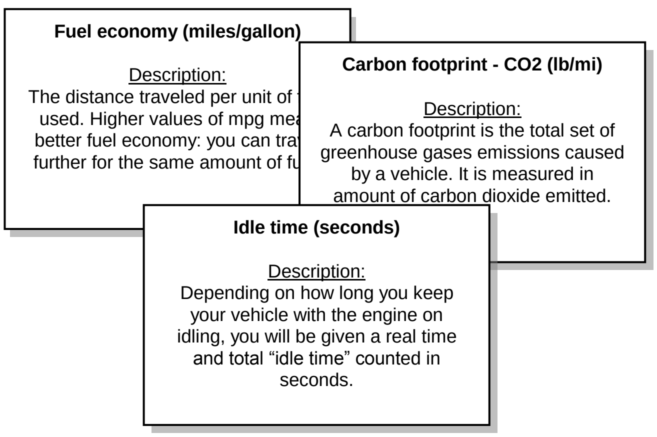

Figure 1: Cards from the driving efficiency information cardsort

The task of this activity was to sort the cards according to preference. The source of these information items was car systems and portable devices currently being sold in the U.S. market.

2.2.4 Part 4: Cardsorting with information visualizations

For the second cardsorting exercise, participants were presented with cards featuring different types of visualizations that a car or portable device in a car could show to indicate driving efficiency. The list consisted of 11 different visualizations, such as Diagram graphs, Single score number, and Tree graphics. Each visualization type was printed on an index card with a label and two to six example graphics, as shown in Figure 2 below.

The task of this activity was to sort the cards according to preference. The source of these visualizations was car systems and portable devices currently being sold in the U.S. market.

2.2.5 Part 5: Evaluation of benchmarked features

This paper-based questionnaire presented participants with a list of eco-features, such as system functionality, information, tools for transportation, and navigation. The list consisted of nine different features, such as “My car offers public transit info” and “My car can pre-calculate CO_2 emissions for a trip”.

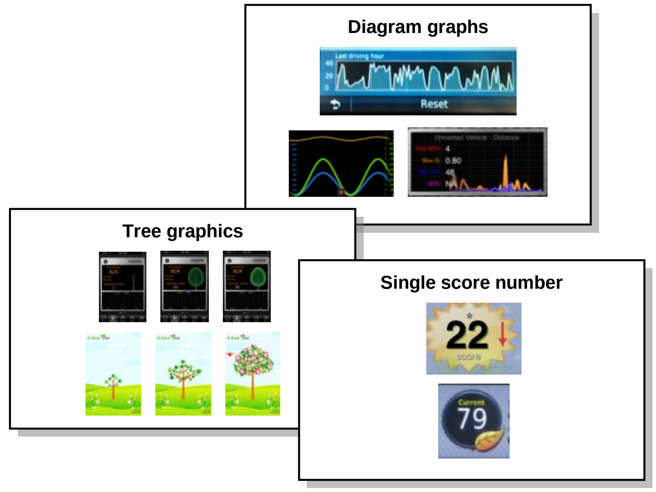

Figure 2: Cards from the information visualization cardsort

The task was to individually rate the features based on how much they like them, on a 5-point scale (Like, Somewhat like, Neutral Somewhat dislike and Dislike). As with the cardsort material, the source of these features was car systems and portable devices currently being sold in the U.S. market.

2.2.6 Part 6: Ranking of rewards for fuel efficient driving

The last part of the study aimed to gather participants’ evaluations of various rewards for fuel efficient driving. In this exercise, participants were asked to individually rate each reward’s importance on a 5-point scale (Agree, Somewhat agree, Neutral, Somewhat disagree, Disagree). Furthermore, they were asked to rank the rewards according to importance.

To avoid any bias toward specific reward keywords, the rewards were presented without a label, but with a description of 2-3 example statements for each instead. For example the monetary reward was presented as shown in Figure 3 below.

Reward type C Rank: ____

Example statements:

- I save $50 a year on gas when I drive my car efficiently.
- The government pad me $2,000 back for purchasing an energy-efficient vehicle.

Question: **“This reward is important to me”:**

Agree	Somewhat agree	Neutral	Somewhat disagree	Disagree
□	□	□	□	□

Figure 3: Monetary reward representation

3. RESULTS

The study’s qualitative and quantitative results are analyzed below. These results provide insights on customer behavior, attitudes, and trends, which can be used to design an interface that drivers will adopt and use to improve their fuel consumption.

3.1 General background and Eco-questionnaire

The following graphs are drawn from results of the General background questionnaire and Eco-questionnaire. As seen in Figure 4 below, a positive significant correlation (Kendall’s tau;

r=.284; p=.023) was found between the participants' Eco-score and their education level. This means that people with higher levels of education have a higher score in the Eco-questionnaire, which indicates that they are more eco-friendly.

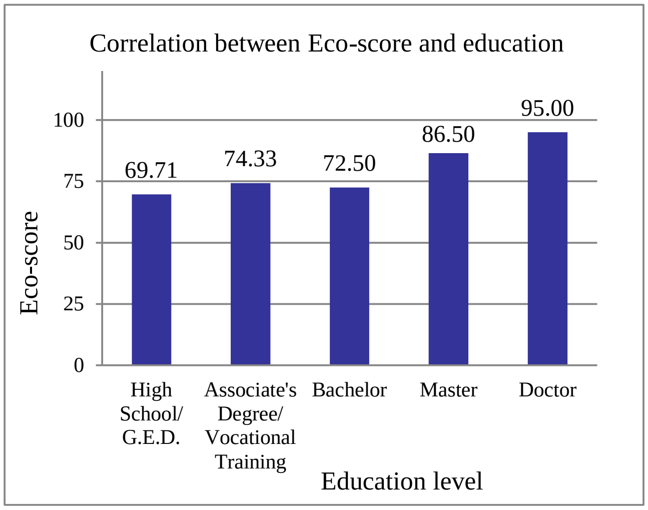

Figure 4: Correlation between Eco-score and education

Similarly, a significant positive correlation (Pearson; r=.490; p=.001) was found between the participants' Eco-score and their age, as seen in Figure 5. This means that on average people who are older have a higher score in the Eco-questionnaire, which indicates that they are more eco-friendly.

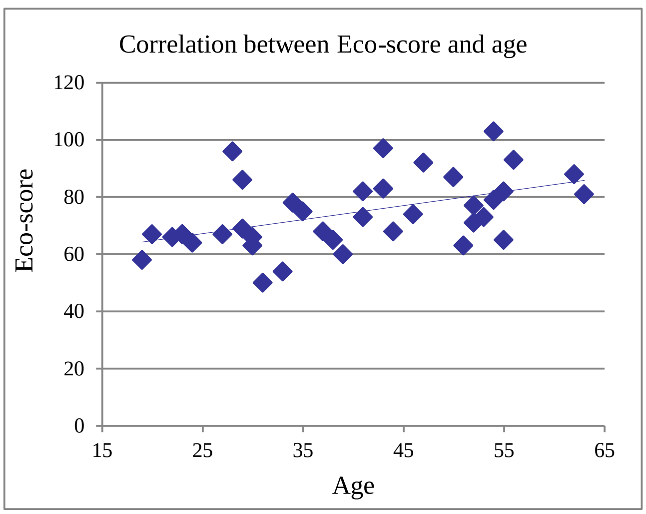

Figure 5: Correlation between Eco-score and age

An interesting question we investigated is whether the longer people have lived in the San Francisco Bay Area, the more environmentally conscious they become. This idea is drawn from the fact that this area is home to numerous startup companies, high-end technology and new trend setters. In addition, as already mentioned, the state government actively supports environmental awareness with tax credits and other similar policies. We purposefully recruited participants who have lived in the San Francisco Bay Area for minimum 5 years, expecting to see that the longer a participant had lived there the higher they would perform on the Eco-questionnaire. On the contrary though, the results show that the participants' Eco-score is not dependent on the number of years they have lived in this area (Pearson; r=.233; p=.147). In other words, living in this area does not make one more environmentally conscious or eco-friendly.

3.2 Cardsorting with driving efficiency information

Table 1 below shows the full ranking of the driving efficiency information cards. Cards featuring score-related information such as Braking score, Overall score, Smooth score and Speed score were all ranked below the middle. At the same time the top three ranked cards featured a form of raw information (e.g., MPG, GPM, $/mile). This indicates that participants prefer information and values that are more direct, rather than abstract (such as an artificial score value).

Table 1: Cardsort ranking: driving efficiency information

Rank:	Driving efficiency information:	Average rank:
1st	Miles/gallon	2.88
2nd	Gallons/mile	4.96
3rd	Average fuel cost ($/mile)	5.55
4th	Total fuel cost ($)	6.65
5th	Total fuel used (gallons)	6.80
6th	Total money saved $	7.23
7th	Carbon footprint CO_2	8.75
8th	Fuel rate (gallons/hr)	8.80
9th	Braking score	9.58
10th	Required engine power	9.65
11th	Energy impact (oil barrels/mile)	9.70
12th	Overall score	9.93
13th	Smooth score	10.00
14th	Speed score	10.93
15th	Drag	12.25
16th	Idle time	12.35

3.3 Cardsorting with information visualizations

Table 2 below shows the full ranking of the information visualization cards. Figure 6 shows the top three cards of the ranking.

The Leaf and Tree graphics cards are the last two cards by rank (10th and 11th respectively). This indicates that compared to other visualizations, people do not like tree and leaf graphics for displaying driving efficiency information. These two visualizations are pretty similar to each other and the fact that they were both individually ranked equally low reinforces this finding.

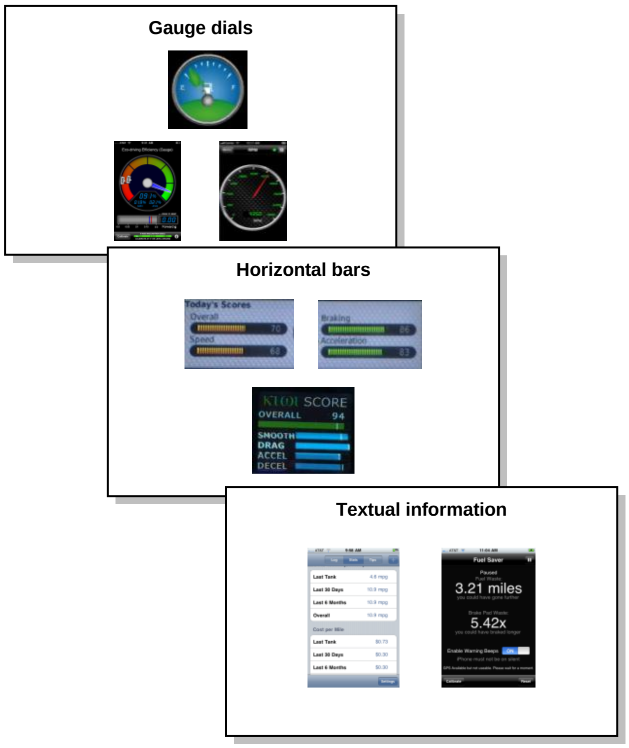

Figure 6: Top three cards of the information visualization cardsort ranking

This result is surprising given the number of consumer electronics, devices, and vehicles that feature such graphics in the market today. A handful of automotive manufacturers showcase graphics, such as growing leafs and vines in their instrument clusters, which track and reward the driver's efficiency. Similarly, portable navigation devices and smart phone applications also follow this design theme with trees, leaves, and plant graphics.

Taking a closer look at the low-ranked Leaf graphics card, a significant correlation (Kendall's tau; r=-.299; p=.017) was found between the participants' income and the ranking of this card. Figure 7 below shows this correlation, which indicates that people with a higher income like Leaf graphics more than people with a lower income.

As seen in Figure 8 below, a correlation (Kendall's tau, r=.246; r=.049) was found between the participants' income and the ranking of the Diagram graphs card. This indicates that people with lower income like Diagram graphs more than people with higher income. Note that Diagram graphs were ranked 7th out of 11 cards, as shown in Table 2.

The last interesting finding in the cardsorting section was found in the ranking of the Textual information visualization card. Figure 9 below shows a significant correlation (Mann-Whitney U-Test; z=-2.040; p=0.044) between the participants gender and the ranking of the Textual information card. Female participants liked this visualization more than male participants. This indicates that females possibly prefer direct instructions in the form of a textual sentence, rather than another visualization which requires further interpretation. Note that Textual information was ranked 3rd out of the 11 cards, as shown in Table 2.

Table 2: Cardsort ranking: information visualizations

Rank:	Information visualization:	Average rank:
1st	Gauge dials	3.80
2nd	Horizontal bars	4.20
3rd	Textual information	4.28
4th	Vertical bar diagrams	4.90
5th	Mini icon on map	6.00
6th	Single score number	6.28
7th	Diagram graphs	6.98
8th	Images other than leaves and trees	7.13
9th	Bubble diagram with leaves	7.40
10th	Leaf graphics	7.40
11th	Tree graphics	7.65

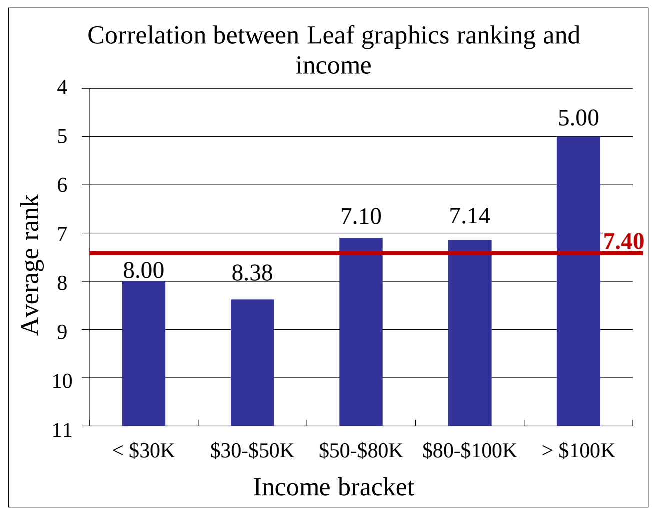

Figure 7: Correlation between Leaf graphics ranking and income

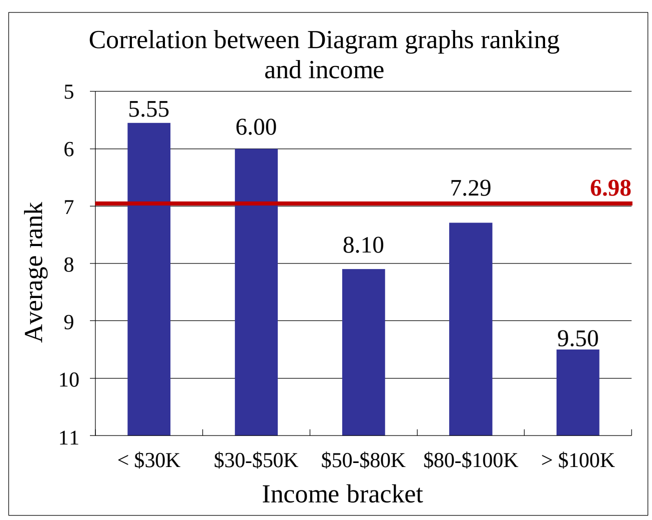

Figure 8: Correlation between Diagram graphs ranking and income

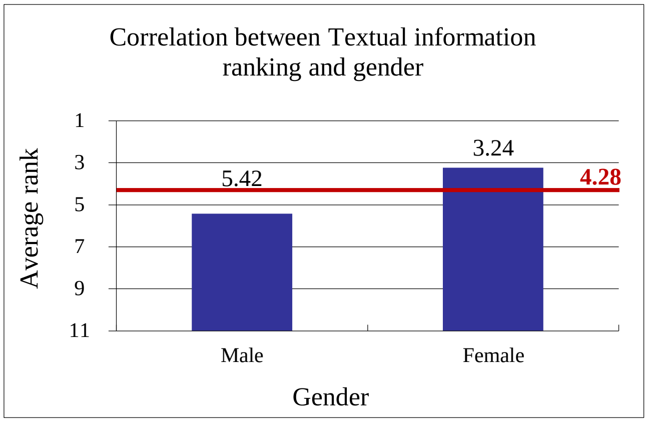

Figure 9: Correlation between Textual information ranking and gender

3.4 Evaluation of benchmarked features

Table 3 shows the rating of benchmarked features that the participants were presented with. Participants rated real-time driving features high, such as Energy consumption monitor as well as Driving tips and Driving tutorials. On the other hand, some features that showcase connectivity with other drivers/customers were not rated high, such as Green community connect and Car pool connect (last two in rating). This indicates that participants do not like features which require interaction with other drivers/customers as much, when it comes to energy efficient driving.

3.4.1 Qualitative feedback

Some qualitative feedback was collected in this exercise. Participants were asked to give their own ideas about features they would like to have in their next car. Some notable comments are listed in Table 4 below.

Table 3: Rating of benchmarked features

Feature:	**Average rating:**
Energy consumption monitor	3.43
Driving tips	3.35
Driving tutorials	3.25
Recycling center POIs	3.00
Pre-calculation of CO_2 for a trip	2.88
Info for public transportation	2.65
Green POIs	2.48
Car pool connect	2.25
Green community connect	1.98

Table 4: Features suggested by participants

Participant:	**Suggested feature:**
P15	Get rewarded with coupons and prizes for fuel efficient driving.
P40	Get awarded with discounts of buying gas for fuel efficient driving.
P16	In-car tutorial on how to improve driving, including safety tips (such as counting to 5 before entering an intersection).
P01	Provide directions to slow down or speed up to catch all the green lights (ride the green wave).
P20	Navigation system could show which route is most efficient in terms of CO2 or fuel use.
P38	The car can help the driver organize upcoming errands and provide an appropriate fuel efficient route.
P38	The car can track the vehicle's weight and alert the driver when it is too high.

3.5 Ranking of rewards for fuel efficient driving

Figure 10 below shows the ranking of the six reward types that participants were presented with. This result is aligned with published research by Lee et al. [11] which shows that money is an important reason for which people would like to improve their fuel efficiency.

It is interesting to note that the last two rewards (Competition and Social recognition) are the only ones that have to do with other drivers/customers. Similarly to the Evaluation of benchmarked features discussed above, this is the second point in our results where rewards that require interaction with other drivers/customers were not ranked high.

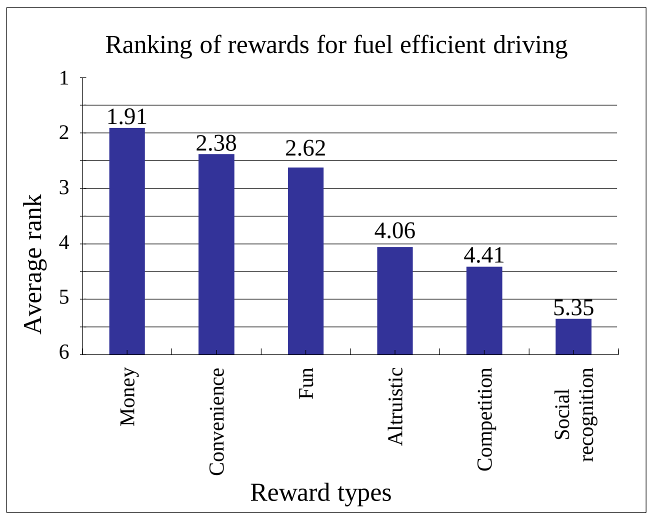

Figure 10: Ranking of rewards for fuel efficient driving

A closer look at the results revealed a couple of interesting correlations between the participants' age and the rewards ranking. A correlation (Pearson; $r=.460$; $p=.006$) was found between the participants' age and the reward Convenience. Furthermore, a correlation (Pearson; $r=.389$; $p=.023$) was found between the participants' age and the reward Competition. This indicates that when it comes to rewards for fuel efficient driving, Convenience is more important to older people, whereas Competition is more important to younger people.

The reward Competition was further tested in our experiment to give a breakdown for different types of competition. These were broken down to distinguish between competition with one's own score, competition to reach an arbitrary 100% goal, and competition with others. As seen in Figure 11 below, participants preferred best to break their own score.

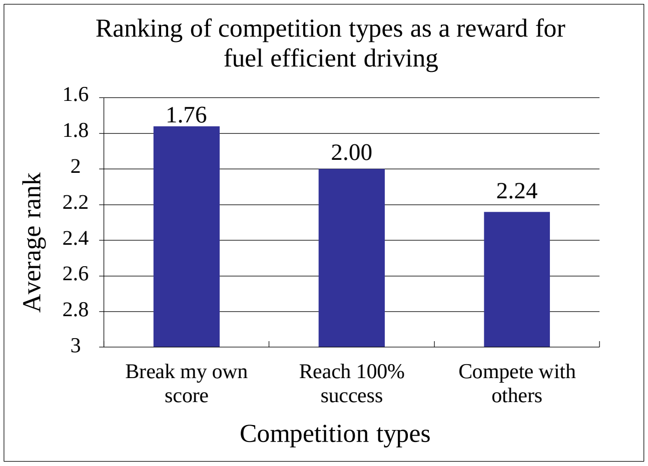

Figure 11: Ranking of competition types as a reward for fuel efficient driving

It is interesting to see that Competing with others was ranked last as it is linked to the results of the Evaluation of benchmarked features discussed above, as well as the Reward type ranking in this section. This is the third point in our results where the competition type that involves interacting with other drivers/customers was not ranked high.

4. DISCUSSION

This paper discusses the methodology as well as the results of our participant study that analyzes incentives for eco-driving. Responses were collected from 40 participants using paper-based questionnaires, and sessions were conducted in an interview style manner. The results include evaluation of different eco-features, ranking of different types of information and visualizations, as well as evaluating different kinds of rewards for fuel efficient driving.

Our results provide qualitative and quantitative analyses to questions about preference and importance. It would be interesting to hold the experiment sessions inside a vehicle, so as to provide a more automotive atmosphere to the participants while giving their responses. The material that is covered by our experiment could also be tested in a different manner, besides paper-based questionnaires. For example, the cardsorting material for driving efficiency information and information visualization could be tested with task analysis using an electronic display device while driving, which would allow gathering performance besides perceived preference data. Furthermore, a driver simulator apparatus would allow testing for different driving scenarios and environments. Lastly, making a hands-on long term study would reveal if and how participants' behavior would change in the long run.

Our participant pool was purposefully selected among residents of the San Francisco Bay area. A further study could be conducted with participants of other specific geographic locations, or other demographic characteristics, to compare and contrast populations, such as a study that compares populations from Europe, China and North America. Lastly, the span of eco-topics in our study is pretty broad, allowing us to get a glimpse at the big picture of things. Targeting the topic more towards the automotive environment could yield more detailed results, and provide more precise design guidelines for designing in-car interfaces.

5. CONCLUSIONS

The insights gained from our study are useful for designing incentives and tools that help drivers improve their vehicle's energy efficiency.

Our results have given an indication of how participant characteristics relate to their eco-friendliness. According to our study, people with higher levels of education as well as older people have a higher score in the Eco-questionnaire, which indicates that they are more eco-friendly. Our initial hypothesis, that the longer people have lived in the San Francisco Bay Area the more eco-friendly they become, was rejected since no correlation was found between the participants' Eco-score and the number of years they have lived in the area.

The cardsort exercises showed that the preferred information types for driving efficiency are Fuel economy (miles per gallon), Fuel consumption (gallon per mile), and Average fuel cost ($/mile), while abstract values such as Speed score were not ranked high. The preferred information visualizations are Gauge dials, Horizontal bars, and Textual information, while the latter was ranked significantly higher by female participants. Visualizations with Leaf and Tree graphics were not ranked high, which is an interesting finding given how often these are found in systems in the market today.

Our study showed that the top three rewards that people would like to receive for their fuel efficient driving are Money, Convenience and Fun. These rewards can be designed and used in smart ways in order to nudge drivers to improve their driving behavior.

Lastly, there were three parts in the results which indicate that people do not like features which require interaction with other drivers or customers, when it comes to energy efficient driving. These were the low rating of such benchmarked features, the low ranking of such reward types, and lastly, the low ranking of the equivalent competition reward type.

These results can be taken into account when designing a new product for a specific customer category or profile. The information and visualization results can be taken into consideration when designing real-time feedback systems. The reward types ranking can be used to design key incentives for the customer's experience inside and outside of the car. Taking all this information into account has provided us with a good starting point for designing and improving eco-features for today's drivers.

6. ACKNOWLEDGMENTS

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