EcoChallenge: A race for efficiency

Ronald Ecker, Philipp Holzer, Verena Broy
BMW Group Research and Technology
ronald.ecker@bmw.de

Andreas Butz
University of Munich (LMU)
butz@lmu.de

ABSTRACT

Careful use of the limited remaining fossil energy resources is important for both ecological and economical reasons. In addition to technical improvements, fuel consumption of a vehicle is influenced significantly by the driving behavior. Currently, only few in-car user interfaces are trying to promote a more fuel-efficient driving behavior. We propose EcoChallenge, a community- and location-based in-car persuasive game with the goal to motivate and support a behavioral change towards a fuel-saving driving style. We implemented and integrated EcoChallenge in an experimental vehicle and evaluated it in a field study. The results regarding acceleration, deceleration, breaking and coasting show the effectiveness of our approach. In addition, users confirmed a very positive experience with our system.

Author Keywords
Efficiency, in-car user interface, persuasive interface, game, competition.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Experimentation, Human Factors.

MOTIVATING DRIVERS FOR EFFICIENCY

Reducing the fuel consumption of cars is an important goal in view of rising oil prices and widely increased ecological awareness. In addition to technical improvements, driving behavior alone can influence energy usage by up to 50% [4]. In order to use this potential, drivers often have to change their learned models of driving and must be motivated to adopt a new way of driving their car.

Persuasive technologies are aiming at this type of behavioral change. They provide people with proper information to reflect on and change their attitude [6]. Persuasive games, in particular, boost their players" intrinsic motivation and can be designed less obtrusive and patronizing [2]. Currently, advice is often given in a quite obtrusive way, as for example in seat belt warnings or parking assistants, to name the most widespread examples. In order to motivate efficient driving, advice should be provided in a more positive and unobtrusive way. As adopting a more ecological way of maneuvering a car is not directly related to road safety, people don't have to be forced to do so. Therefore, persuasive games appear to be an appropriate approach to achieve this kind of behavioral change.

Figure 1: The location-based challenge system, integrated into the experimental vehicle.

There are currently two main ways to teach drivers about an efficient driving manner. The first category directly addresses low level driving functions by giving drivers real-time feedback[1,2] via gear shift recommendations[3], ambient interfaces, or haptic sensations in the gas pedal. This feedback is mostly designed to discourage high speed and high acceleration or deceleration values. Meschtscherjakov et al. [7] investigated the acceptance of recent and upcoming eco-feedback systems based on the Technology Acceptance Model [3]. They found that visual feedback on whether the driver is currently driving in an ecological manner received the highest acceptance. Real time visual feedback is also used in smart phone applications[4] or mobile navigation systems[5] utilizing the device's acceleration or GPS sensors.

The second category of interfaces shows drivers their efficiency as a history of fuel consumption, often combined with community rankings or real time feedback. Systems like the Fiat EcoDrive[6] use a statistics- and community-based approach, offering the analysis of recorded journey data within an online community. Using these systems, users can receive hints for improving their fuel efficiency and can compare their past journeys and overall achievements from their home computers.

MobileHCI 2011, Aug 30–Sept 2, 2011, Stockholm, Sweden.

[1] Ford SmartGauge: http://media.ford.com/images/10031/SmartGauge.pdf
[2] Honda Eco Drive Assist System: http://world.honda.com/news/2008/4081120Ecological-Drive-Assist-System/
[3] BMW Efficient Dynamics: www.bmw.de/efficientdynamics
[4] GreenMeter: http://hunter.pairsite.com/greenmeter/
[5] Garmin: http://www8.garmin.com/buzz/ecoroute/index.html
[6] Fiat EcoDrive: http://www.fiat.com/ecodrive/

Our approach combines the advantages of both categories and enhances the user experience by adding real time community features in order to create a persuasive game-like interface for the propagation of fuel efficient driving strategies. A fully functional prototype was implemented in an experimental vehicle using all available in-car displays in order to evaluate the impact onto the driving task.

THE DESIGN OF ECOCHALLENGE

Our main design goal was to encourage fuel-efficient driving in a playful and unobtrusive way. Following this premise, the basic concept of EcoChallenge was derived through an analysis and combination of Game Design Patterns [1] suitable for an automotive environment. We combined the patterns *Social Rewards*, *Common Experiences* and *Physical Navigation* to create a persuasive game in the form of a multiplayer fuel efficiency driving contest.

To test the persuasive potential of our concept, we chose to promote a specific driving strategy by our prototype system. As we previously showed [5], a driving comparison which solely focuses on minimal fuel consumption can lead to undesired driving behavior, such as driving too slow or avoiding breaking. We therefore chose a strategy that relies on a mix of speed and fuel efficiency. This strategy encourages a speedy acceleration towards the drivers target speed, coupled with an increased anticipatory use of coasting for deceleration. This means that the driver has to anticipate whether the energy built up during strong accelerations can be used for coasting later on, or whether a modest acceleration can avoid a following, inefficiently strong deceleration. The strategy is intended to sensitize the driver for the mechanics of efficient driving and to ensure that his main focus stays on his primary driving task. Should long-term studies show that a different strategy combines efficiency and road safety in a better way, EcoChallenge can be adapted to different strategies as well.

To measure the efficiency of a driver, we used a simplified version of the metric used by Dorrer et al. [4] who originally assumed that the general maintenance of a (rather low) constant speed leads to the most ecologically efficient results. In contrast, we chose to award driving maneuvers with an optimal proportion of speed and fuel usage. The formula in Figure 2 was used to compute bonus points for the driver every 100 meters, awarding a long time spent on minimal fuel consumption combined with speed.

$$\boldsymbol{Bonus} = 1 - \sqrt{\frac{avgCons}{vehCons * 2}} * \left(constSpeed * \sqrt{\frac{avgSpeed}{constSpeed}} \right)$$

Figure 2: avgCons = average consumption over the current segment in liters/100km, vehCons = constant consumption value for the vehicle in liters/100km, avgSpeed = average speed during the current segment in km/h, constSpeed = a predefined speed constant in km/h.

To convey this strategy, we developed a visual concept using the in-car displays for real-time feedback while driving. First, a questionnaire answered by 18 subjects helped us to identify desired or expected display elements that could support the EcoChallenge concept. Based on these results a paper prototype (representing the car‟s interior) was created and shown to 12 subjects in order to test the concept as well as combinations and layouts of suitable UI elements. The results of the paper prototype study and questionnaires led to three main display elements:

1. An advisory feedback display showing areas of efficient acceleration and deceleration.

2. A real-time ranking of the driver„s behavior in comparison to other contestants as a rank indicator of the driver. The knowledge about their actual rank is meant to motivate drivers to perform well in their stabilization task.

3. A driving history (Figure 3) generated during a challenge, which shows the drivers speed profile as a curve in comparison to the speed profile of the best run so far, and which also integrates a visualization of the points earned in this run. The aim of the history display is to allow a deeper analysis of one‟s own driving strategy and a comparison with other drivers or own previous results. This history provides direct feedback during a run as opposed to a disjointed breakdown after the driving process.

Figure 3: Interface in the instrument cluster display. Left: Acceleration and deceleration advice, where red indicates wrong, green proper and gray neutral maneuvers. Center: challenge history with the reference speed profile (thin orange line), own speed profile (thick orange line) and the earned points (blue bars). Right: current ranking and total number of competitors.

The available displays for these three core elements are a freely programmable instrument cluster, a head-up display projected onto the windshield and the 10,25“ central information display in the vehicle's center stack.

The prototype uses a client-server architecture. The visual interfaces for all three displays are created as separate but connected Flash® executables and form the locally installed client of our system. The vehicle's signals (speed, consumption and acceleration etc.) are read from the CAN bus and used by the client applications. The user base, predefined challenges and recorded challenge runs are stored on a remote server. The client also sends the current GPS connection to the server in order to request information about predefined challenge routes in the area. Challenges and waypoints are defined using Google Earth .kml files and imported into the server. If the car finds itself close to the starting point of a stored challenge, the server supplies the client with the necessary coordinates and challenge information, including the number of players that drove the challenge before, and the best run so far. This top run is then used as a reference for the history display (see Figure 3).

The client will then highlight the upcoming starting point and guide the driver through the challenge route. Once a driver crosses the starting point of a challenge, the client sends its driving data (current state) to the server, which computes the points and ranking for the driver's run and adds the new run to its database. The system was integrated into an experimental vehicle (BMW 5.30i) as illustrated in Figure 1.

EVALUATING ECOCHALLENGE

As shown in [5], driving-related games can also impact the driving style in a negative way. In addition, we wanted to capture user reactions under realistic conditions, because different traffic situations also influence the ranking. In order to evaluate all these effects in addition to the potential positive effect on driving behavior, a field study seemed most suitable.

Hypotheses

The main goal of the location-based challenges is to motivate drivers towards a more anticipatory and efficient driving strategy characterized by the development and maintenance of kinetic energy. Adherence to this strategy can be observed by analyzing the acceleration and deceleration of the vehicle. The implemented system fosters a quick (2/3 throttle) acceleration and a slow deceleration (few strong breaking maneuvers and a long coasting phase). We had the following hypotheses:

H1: Drivers drive more in the coasting mode and avoid needless breakings when the EcoChallenges are running.

H2: Drivers accelerate more quickly to achieve the desired speed by conducting the EcoChallenges.

H3: Less fuel is needed when the EcoChallenges are used.

H4: Positive emotions and an intrinsic motivation are created by the EcoChallenges.

Experimental Design

In order to evaluate the location-based EcoChallenge system, a repeated measures within-subject study was conducted. All participants had to drive three previously defined challenges using the system (each approximately 1.3 kilometers) in a row, as well as a baseline condition (same route without the system). The order was counterbalanced. No instructions regarding the driving style were given. Only the interface was explained to the users. As dependent variables, the speed, braking force and braking ratio, acceleration and deceleration ratio, fuel consumption and coasting ratio during driving were captured. The subjective user preferences were captured by a questionnaire regarding different aspects of the system. To ensure similar traffic conditions for all participants, previously defined time slots outside of the local rush hours were chosen (9:30 – 10:30, 11:00 – 12:00, 13:30 – 14:30, and 15:00 – 16:00). The test track was located within the municipal area of Munich and comprises 15 traffic lights and 75 percent of multilane road. It represents a relatively typical urban route in this area.

Participants

We recruited 37 volunteers between 21 and 59 years (average 38.3 years). The extremely uneven distribution of 35 male and two female participants was caused by the fact that only test engineers with a special license were allowed to drive the experimental vehicle. One data set had to be discarded because of a technical failure.

Results

For all dependent variables we computed a repeated measures ANOVA test for detecting main effects. Post-hoc pairwise comparison used Bonferroni correction. The location-based challenge system has a significant impact on the score comprising consumption and speed as described in System Design. All runs and the overall score ($F(1, 73) = 45.672$, $p < .001$) were higher in the challenge condition (Figure 4 left). Furthermore the test drivers were breaking with less force during a challenge when looking at the overall breaking force ($F(1, 73)= 6.044$, $p=.020$, Figure 4 right).

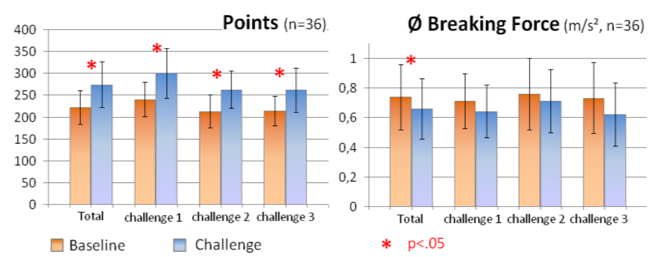

Figure 4: Left: Score achieved in the baseline and challenge condition. Right: Average braking force as deceleration (m/s^2).

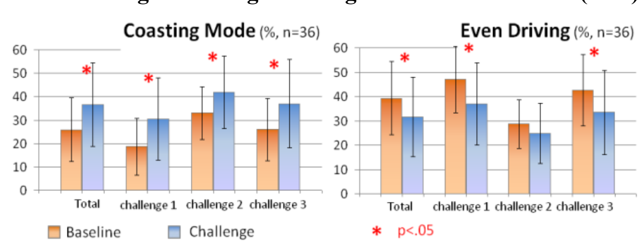

Figure 5: Percentage of coasting (left) and even driving (right).

As intended, participants were driving a significantly higher percentage in coasting mode during the challenge condition ($F(1, 73)= 16.050$, $p < .001$) as illustrated in Figure 5 left. Coasting mode means decelerating without breaking, either in neutral or a different gear. Consequently driving with even speed (Figure 5 right) was used less ($F(1, 73)= 8.807$, $p = .006$) and less breaking maneuvers were needed (Figure 4 right). The system also encourages speedy acceleration

(2/3 throttle). As demonstrated in Figure 6, participants accelerated the car significantly faster (F(1, 73)= 17.382, p < .001) which results in significantly less acceleration time (F(1, 73)= 9,417, p = .004) over the test track. The desired speed was reached faster and coasting can be used earlier.

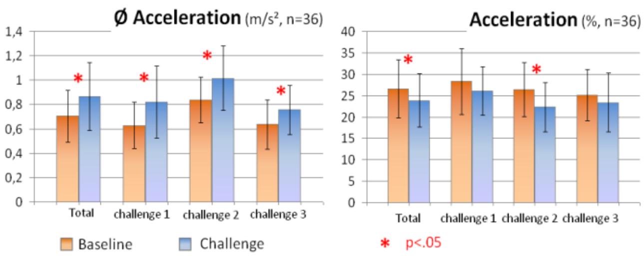

Figure 6: Left: Average acceleration in m/s^2. Right: Percentage of acceleration.

While no significant impact on the average fuel consumption could be found (baseline mean 9.2 liters per 100 km, challenge mean 9.0 liters per 100 km, F(1, 73)=.126, p = .724), the average speed was faster during the challenge condition without needing more fuel (baseline mean 31 km/h, challenge mean 34 km/h, F(1, 73)= 3.947, p = .056).

While this shows that drivers adhered to the intended driving strategy much better in the challenge condition and thereby documents the effectiveness of EcoChallenge, it also means that the overarching goal of saving fossil energy was not met in the way intended. Choosing a better or more refined driving strategy could fix this shortcoming. In addition, our approach bears the potential to let the community develop a strategy by itself in an evolutionary way.

At the end of each trial, we asked participants about their acceptance. All questions had to be answered on a Likert scale from one to five (where one meant "I totally disagree" and five for "I totally agree"). Concerning the subjectively perceived influence onto the driving style participants attested a big impact (4.4). Also the subjectively sensed efficiency was high (3.7). The most positive answer was given to the question about the joy of use (4.5). Furthermore participants felt only little pressure (2.5) and distraction (2.7).

In addition participants had to estimate the usefulness of the three display elements. The acceleration/deceleration advice was perceived as most useful (4.0), the community ranking second (3.3) followed by the history (3.2).

Formally, H1 can be accepted based on the results of our experiment. Drivers were coasting more often in the challenge condition, which resulted in less strong breaking maneuvers. As intended, H2 could also be accepted because subjects accelerated more quickly when using the location-based challenges. H3 has to be rejected, but we found that users tended to drive faster and needed marginally less fuel. At the same time participants did not feel forced or patronized during a challenge. In contrary they felt fun and motivation while driving more efficiently. The widespread conception that efficient driving is boring and annoying could thus be dispelled. Therefore, H4 can be accepted.

SUMMARY AND FUTURE WORK

We have presented the design and prototypical implementation of EcoChallenge. It combines location-based information and community data in order to create a competitive driving situation with the goal of fostering a more efficient driving behavior. In a user study, we have verified the persuasive power of our system. As hypothesized, users adopted a driving style closer to a given driving strategy. The hypothesis of lower fuel consumption could not be accepted, but our approach can educate drivers towards arbitrary strategies, hence picking a more efficient driving strategy will overcome this flaw. As stated in [5] a strategy encouraging slow driving also results in positive user feelings. Therefore it is assumed that the user experience can be ascribed to the challenge situation.

The implemented interface was a first attempt to communicate driving strategies in a game-like manner using in-car displays. We did not focus on driver distraction in our study, which will need further investigation in the future. Furthermore, context information should be considered to achieve a fairer assessment of the driving performance. Control mechanisms have to be implemented to ensure compliance to the traffic rules. For example, the negative effects of simply driving very slowly (as mentioned in [5]) could be eliminated by adding *speed* to the ranking criteria.

Finally, the long-term effects of our approach remain speculative. The question, whether EcoChallenge will alter driving behavior on a permanent basis can only be answered in a long-term study, which was impossible to conduct with the experimental vehicle at hand.

REFERENCES

1. Björk, S., Lundgren S., Holopainen, J.: Game Design Patterns. In: Level Up: Digital Games Research Conference 2003, Utrecht. 2003.
2. Bogost, I.: Persuasive Games: The Expressive Power of Videogames. The Mit Press. 2007.
3. Davis, F. D.: A technology acceptance model for empirically testing new end-user information systems: Theory and results. Dissertation, Sloan School of Management, Massachusetts Institute of Technology. 1986.
4. Dorrer, C.: Effizienzbestimmung von Fahrweisen und Fahrerassistenz zur Reduzierung des Kraftstoffverbrauchs unter Nutzung telematischer Informationen. Expert Verlag, 1. Auflage, Renningen. 2004.
5. Ecker, R., Slawik, B., Broy, V.: Location Based Challenges on Mobile Devices for a Fuel Efficient Driving Behaviour. In proceedings of fifth International Conference on Persuasive Technology, Copenhagen, Denmark. 2010.
6. Fogg, B.J.: Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann Publishers. 2003.
7. Meschtscherjakov, Wilfinger, Scherndl, and Tscheligi. Acceptance of future persuasive in-car interfaces towards a more economic driving behaviour. In Proceedings of the 1st International Conference on Automotive User interfaces and interactive Vehicular Applications. Essen, Germany. 2009.