ABSTRACT
Reducing the fuel consumption of cars is seen as a central element in reducing CO₂ production by individuals. The automotive industry currently focuses on more efficient engines and alternative power concepts. Our research complements this by an assessment of how drivers can reduce fuel consumption of their vehicle by changing their behavior. An initial study reveals that individuals have a poor understanding of the cost of driving. Looking at ubiquitous technologies we believe that there is a great potential for saving energy. Information can help to reduce the need for driving. We make concrete suggestions of how user interfaces in the car can make the user aware of the potential of reducing fuel consumption.

Keywords
Persuasive user interfaces, automotive user interfaces, car instruments, ecology-awareness.

INTRODUCTION
Fuel consumption of cars has become a major issue over recent years for individuals as well as for the society. For individuals, the cost of operating a car is, due to increased oil prices, strongly dependent on the fuel consumption. Many societies, particularly governments, are aware of the environmental problems created by driving and are taking actions to fix them, e.g., European Commission [2]. In contrast, car manufacturers have been very successful advertising their cars based on the driving experience (faster acceleration, high speeds, etc.). Therefore, it is important not to impair the driving experience when trying to reduce the fuel consumption.

Many cars provide some indication of fuel consumption. Some cars show the average consumption since the car was last fuelled and others the current consumption. Overall, these visualizations are very coarse and provide only a rough indication of the fuel efficiency of driving. Another approach is to provide hints for more efficient driving. For example, in some current cars with manual transmission, an arrow suggests that the driver shifts to the indicated gear to reduce fuel consumption.

In our research, we focus on the in-situ provision of information to the driver. One central design goal is to create awareness in a pleasant and potentially playful way.

POTENTIAL FOR SAVING ENERGY
There are two dominant ways to save energy: 1) more efficient driving and 2) driving less. Before prescribing any of these methods, it is important to consider the many factors that influence fuel consumption. Studies have already shown that gender, for example, can impact fuel consumption [1]. Also, users can have a significant impact (about 10-20%) themselves. In the following, we discuss potential factors for saving energy and present several designs for user interfaces that can increase the awareness of energy consumption and that behavior has a significant impact. All the designs use persuasive technologies [3], as we assume that a large fraction of the drivers has an interest in economical and hence environmentally-friendly driving.

More efficient driving
Minimizing fuel-expensive actions is the key to more efficient driving. Since a lot of fuel is used when increasing speed, reducing the need to accelerate and then break is a key issue. Information about the projected state of the road (e.g. slower traffic 1km ahead) can also help the driver to drive more efficiently. Also, reducing average speed helps reduce fuel consumption [4].

We suggest a system that gives predictions about how much fuel will be used when driving at certain speeds to a specific destination. By showing users how much (or little) time is gained when driving faster, the system allows them to make an informed decision about whether or not it is worthwhile to consume more fuel (and save time) or not.

Another opportunity to motivate to more efficient driving is to include a “Personal Best”. For a frequently driven route, the lowest fuel consumption at any point on this route is stored. Every time the driver drives this route he gets a visual representation of the current fuel consumption compared to the best (i.e. lowest) fuel consumption at any point. The overall goal is to beat the best fuel consumption and therefore to drive more efficiently. At the end of the route an optional high score list including average fuel consumption and time can be displayed.

Driving Less
An obvious way to reduce fuel consumption is to drive less. In cities, a lot of traffic is due to cars looking for a parking spot (up to 40% according to [5]). Providing additional information on free parking spaces is one option for
reducing this traffic. Several projects investigate such solutions (e.g., [5]). People often drive several times around the block to get a parking space that is very close to their destination. In many cases, parking at the far end of a parking garage (can save driving time and only minutely increases the walking time. To motivate the driver to take such an option, we propose a system that gives the user exact up-to-date information about how much time is required to reach their destination on foot. For instance, a modified navigation system might display this message: “If you happen to see a parking space now – take it! You will only have to walk X minutes and it potentially saves you driving another Y minutes.”

For many individuals, driving is necessary to go shopping for products and services. Looking into means to reduce the number of trips required is a further option to reduce overall driving time and thereby fuel consumption. This can include suggesting merging trips based on recent behavior or proposing alternatives to making the trip at all. Using alternative means of transport (e.g., walking or public transport), or carpooling can also reduce the amount of driving. These options may appear inflexible, however, in many cases, this is due to a lack of information (e.g. who is driving the way I have to go?). Technology can help to provide such information and to make ridesharing and alternative modes of transport more flexible.

FOCUS GROUP
To develop new aids to help drivers become more energy efficient and reduce their fuel consumption, we conducted a focus group with 7 voluntary participants, 3 female and 4 male, 26 to 31 years. Each had a driving license and lives in a metropolitan area in Germany. First, we set out to understand user concerns with regard to technologies that create awareness of fuel consumption. In open discussions, participants were asked about the energy consumption of a car in specific contexts. In the second phase, we showed paper screen designs of potential visualizations and presentations that provide more detailed information on driving efficiency. For example, for the Personal Best approach a comparative visual representation of the current fuel consumption and the best fuel consumption using bar graphs, a simple number representation, or a red light when the current fuel consumption is over the personal best can be used. Participants discussed the pros and cons of each suggested design.

AWARENESS OF ENERGY USAGE
Even though most people use their car daily, it seems that their awareness of the associated cost is limited. In our discussions, it took people a long time (some even started to calculate) to answer the question “how much does a trip by car to your workplace cost?” This is much in contrast to other products or services people commonly use, for which they can normally give price details (e.g., for bus rides) very quickly. The discussions revealed that people are able to reason about cost associated with driving, but they usually do not. Participants seemed to be more aware of the current price per liter of gas than about the cost associated with driving a certain distance.

DESIGN PROPOSAL ‘PERSONAL BEST’
The “Personal Best” design proposal was discussed in more detail. The idea was generally considered interesting but several issues were raised, e.g., whether it also incurs additional stress for the driver. Also, as there are many external factors influencing driving behavior (e.g., heavy traffic, traffic signs) the driver might only have limited influence. One participant suggested comparing fuel efficiency scores between different driving environments, such as ‘on the highway’ versus ‘in the city’, instead of for overall driving. Some expressed concern that after a certain time, one will achieve a score that is hard to beat. However, this could be seen as the goal of the application, where the driver has achieved his or her most economical style of driving, and the application could subsequently be switched off. With regard to the visual presentation, there was agreement that the display should be easy to interpret and unobtrusive. Another suggestion in the focus group discussion was to extend “Personal Best” to a community of drivers to see how one compares to others driving the same or a similar route.

SUMMARY AND CONCLUSION
We investigate the potential for providing in-situ rich information on fuel consumption to the driver to create awareness of economical and environmentally-friendly driving behavior. The paper mentions a variety of factors that can be influenced by presenting additional information on the current fuel efficiency. From early user feedback we conclude that a playful and unobtrusive design would be most appealing. While discussing the designs, it became apparent that much of the functionality can be integrated as extra features in navigational aids. This approach is complementary to other efforts, like improving engine technology. Given the great impact that driving behavior has on energy consumption, we argue that this is an important field that warrants further research.

REFERENCES