Designing a Context-Aware Mobile Application for Eco-Driving

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ABSTRACT
This paper presents the design of a context-aware mobile application for eco-driving based on state-of-the-art data sensing-processing devices for improving effectiveness of driving style. The paper will address human factors' challenges related to the design and delivery of effective, context relevant feedback or audio notifications that can help the user to acquire and improve their level of eco-driving, by minimizing negative effects on user attention and motivation (considering typical app usage over time). The design case presented can inform the future development of more effective *just-in-time* interventions for eco-driving and sustainable mobility.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human Factors.

Keywords
Eco-driving, Context aware mobile solutions, Human Factors, Design case.

1. INTRODUCTION
Eco-driving typically refers to a set of techniques and technical solutions encouraging ecological and economical driving by means of high fuel efficiency and reduction of CO_2 emissions [1][2]. Several systems to assist drivers in acquiring eco-driving styles have been proposed in recent years and made available in commercial vehicles. They can be based on a combination of on-board diagnostic devices for measuring relevant parameters of fuel consumption (e.g., ODBD-II) and state-of-the-art human-machine interfaces providing visual/auditory feedback on eco-driving status, by means of on-board displays or mobile applications [7][8]. Hiraoka et al. demonstrated that by displaying the instantaneous fuel consumption and providing instruction on the key features of eco-driving improves the fuel economy [3]. Van der Voort et al. developed an eco-driving system that enhances the driver's operation both tactically and strategically [4]. Tomiyama et al. investigated the effect of the modality of the eco-driving status display method on the fuel economy and driving behavior [5]. Yoshimura et al. evaluated the annoyance level when using an assist system for eco-driving [6]. Similarly to other mobile interventions and systems for behavior change in the field of sustainability and healthy living, it has been shown that repeated use of these systems may lead to boredom and low motivation of users in complying with the recommendations delivered, if relevant Human Factors (HF) are not properly taken into account. This paper presents the design case of a mobile eco-driving solution based on state-of-the-art monitoring and feedback techniques, which has addressed main HF challenges in the delivery of relevant feedback and notifications to the driver, in order to minimize attention and motivation drawbacks. In section 2 we briefly present our system architecture and the mobile application features encouraging eco-driving. In section 3 we discuss the rules followed to deliver context relevant audio notifications for eco-driving during a journey, by minimizing their negative impact on driver's attention and motivation. We conclude by summarizing our design case contribution as well as next steps in the evaluation of the eco-driving application proposed.

2. SYSTEM ARCHITECTURE AND ECO-DRIVING FEATURES
The eco-driving application designed runs on Android smartphones and retrieves data about driving style from OBD-II Bluetooth diagnostic device, which is installed in the user vehicle. OBD-Il provides access to data from the engine control unit (ECU) of the vehicle, such as acceleration, deceleration, average fuel consumption, speed, engine temperature and transmits data to the mobile phone by Bluetooth connection. The mobile phone of the driver needs to run the Torque Pro application (OBD-II & car), which reads the data on the status of the vehicle and makes it available to the eco-driving application. The eco-driving application consists of an eco-dashboard screen (Fig.1) presenting relevant information to support eco-driving behaviour (e.g., an eco-driving overall score, based on the most recent driving style exhibited by the user during the on-going journey) and report screens showing relevant details on previous journeys made by the driver (e.g., statistics and graphs showing journeys made, CO_2 emissions, fuel consumption etc.). A main support offered by the app consists in providing to the driver context relevant audio-visual notifications (see Fig. 1 for examples of hints displayed the app, which are delivered through text-to-speech if this setting is turned on in the app) encouraging the adoption of ecological and economical driving. These are meant to help the driver improve their behaviour over time, by avoiding too much distraction or intrusiveness with the main task of driving. Gamification techniques are also deployed by the app to support motivation of the user by allowing ranking and sharing of eco-driving scores

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among users within social networks (if the driver is interested in using this kinds of social feature).

3. CONTEXT RELEVANT DELIVERY OF ECO-DRIVING FEEDBACK

Table 1 below shows a list of advices or notifications that should be delivered to a driver in order to improve their level of eco-driving. Advices 1 to 4 are general advices that could be delivered before a journey, whereas the following ones should be delivered during the journey at an appropriate timing in order to have the best effect on driving style and behavior. To achieve this goal we set up some rules and developed an algorithm used by the eco-driving app in order to ensure the most context relevant notifications are sent to the driver during a journey. As an example, notification n. 6 is sent when the app detects the driver is driving at a steady speed, but not using the highest gear possible; notification n. 7 is sent anytime the app detects an aggressive driving style is occurring, with many accelerations and breaks performed during a journey. Notification n. 9 is sent only when the temperature outside the vehicle is equal or above 20 degrees centigrade and the driving speed is above 80 km/h. Notification n. 13 is sent when the app detects (by relying also on the phone accelerometer sensor) that the vehicle is driving up hills, while notification n. 15 is sent when the app detects idling is occurring since a few minutes.

The rules mentioned above have been defined in order to be able to deliver just-in-time, effective advice or notification to the driver, thus supporting eco-driving by minimizing any form of annoyance and excessive distraction of the driver from the main task of driving. Our approach takes into account that eco-driving behavior might take time to be achieved, especially by new drivers or drivers that have already acquired an aggressive driving style, therefore it is important to engage the driver with the use of the app until the desired behavior change has occurred and established in a stable way.

4. CONCLUSION

In this paper we have presented our recent design of an eco-driving mobile application based on *just-in-time*, context relevant delivery of notifications to the driver. In order to improve the effectiveness of the behavior change intervention designed (i.e., acquisition of eco-driving style) and minimize negative effects of the app on the driver's attention and engagement with the app over time, we have discussed a set of rules for notifications delivery, which have been implemented in our app. A long-term trial of the eco-driving app designed will be carried out in September 2014 in the Primiero area (Trento, Italy) involving about 100 car drivers. Results of this evaluation will allow us to further improve and fine-tune the eco-driving intervention designed.

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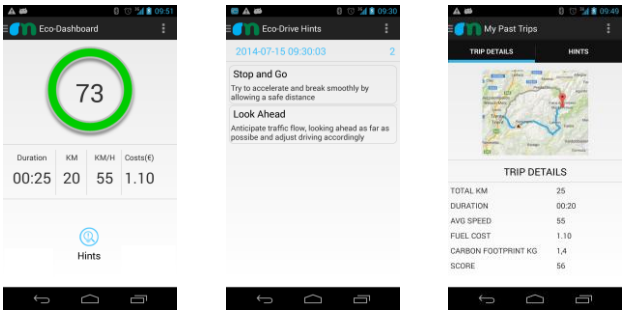

Figure 1. Eco-dashboard of the Android app showing an overall eco-driving score, details on the current journey and *just-in-time* hints to improve driving style based on contextual data.

Table 1. List of eco-driving notifications to be delivered before (1-4) and during a journey [2].

Notification N.	*Example*
1	Maintain the vehicle properly according to the manufacturing standards
2	Consolidate trips to bypass congested routes
3	Unload as much as possible as soon as possible
4	Check tyres' pressures regularly and keep tyres properly inflated
5	Aerodynamic shape of vehicle
6	Drive at a steady speed by using the highest gear possible
7	Accelerate and break smoothly by allowing a safe distance between vehicles
8	Decelerate smoothly using the retarder and the engine break
9	Close windows at high speeds
10	Anticipate traffic flow (look ahead and adjust driving accordingly)
11	Minimize the use of heating and air conditioning
12	Use of the cruise control
13	Driving up hills: use the highest possible gear with almost max acceleration
14	Decrease speed to avoid unnecessary overtaking of other vehicle
15	Avoid idling altogether
16	Avoid driving through the city center

More specifically, we intend to optimize the context awareness of the eco-driving guidance provided and properly adapt the intervention to the driving style of the user (and its change) over time.

5. ACKNOWLEDGMENTS

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