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Study of a mobile app interface supporting behaviour change in electric vehicles use

S. Fruttaldo [1], R. Montanari [2], T. Ross [3], A. Morris [4]

[2] Affiliation: RE:Lab srl
E-mail: roberto.montanari@re-lab.it

[1,3,4] Affiliation: Loughborough University
E-mail: S.Fruttaldo@lboro.ac.uk, T.Ross@lboro.ac.uk, A.P.Morris@lboro.ac.uk

Abstract

This paper is based on a study aimed at examining how historical data on energy consumptions in electric vehicles could be (re)designed by taking into account Kahneman's theories (in particular "Fast and Slow thinking", Kahneman, 2011 and "Prospect Theory", Kahneman & Tversky, 1979): they should be applied to support driver's behaviour changing, in particular eco-driving, by focusing on loss rather than gain.
This paper describes i) the design of an HMI concept as part of a mobile app, providing information on energy consumption in two versions (loss/gain of recovered km). It is based on a literature analysis on energy use behaviour and eco-driving and an analysis of information systems for home energy use and instrument clusters already in use in electric vehicles (Fully Electric - FEV and Hybrid - HEV, ii) a heuristic evaluation of the HMI concept; ii) outcomes from a co-design session.

Keywords: Electric Vehicles (EV), HMI, User interface, information visualization, driving behaviour change.

1.   Introduction

1 1.The study context

Information on historical energy consumption provided by current electric vehicles on the market typically do not fully support drivers in changing their consumption behaviour: current eco-driving systems, in most cases represented in graphical form, are more suitable for investigation and interpretation using desk-analysis criteria rather than being interpreted and used in the mobility context. Furthermore, they do not include information that may be relevant to the user in order to understand how energy has been consumed (e.g. road slope, type of route i.e. urban, extra-urban etc.)
This study examines how such data provided by a mobile app could be (re)designed by taking into account Kahneman's theories. Of particular relevance are his theory of Fast and Slow thinking and "Prospect Theory" (Kahneman, 2011; Kahneman & Tversky, 1979). The study examines how these theories can be applied in order to support the driver in changing his/her driving behaviour, in particular eco-driving, by focusing on loss rather than gain.

1.2 Study aims

The scope of the study is to understand how to change behaviour through data visualization: in particular, to investigate how to influence «wrong» driving behaviour via the (re)design of the information provided by historical data (or how to encourage better, safer driving behaviour by delivering more accurate and readable information to the driver on a range of vehicle and driver performance metrics based on good design principles).

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Historical data are taken into account: this choice is due to the fact that based on such data the driver can access information on his driving behaviour (over a longer period of time) and understand which aspects can be improved (e.g. acceleration, regenerative braking,…).

As the overall aim of this study is to contribute to the design of successful HMI supporting eco-driving, the final output will be a proof of concept and recommendations for information systems supporting eco-driving.

In this paper results from the first study planned in the project are presented. It included different stages:

- Based on outcomes from a previous Literature review, a draft HMI concept was created;
- The draft HMI concept was evaluated by experts in a Heuristic evaluation;
- Suggestions from the Heuristic evaluations led to organizing a co-design session: participants drafted a new concept of the app also taking into consideration the instrument cluster.

2. *Design of an HMI concept of a section of a mobile app*

According to findings from Literature analysis, the design of an HMI concept of a section of a mobile app was carried out. This section of the app aims to provide information on energy consumptions in two versions (loss/gain of recovered km), according to Kahneman's studies on Fast and Slow thinking and his Prospect Theory (Kahneman, 2011; Kahneman & Tversky, 1979). In particular, instant and historical energy consumptions data could be referred (respectively) to System 1 and 2 proposed by Kahneman (Kahneman, 2011), corresponding roughly to the familiar distinction between intuition and reflection.

Recovered kms is energy, expressed in kms, actually recovered e.g. from regenerative braking; Recoverable kms is the optimal energy recovery that the vehicle could get if used at its most (with no acceleration/deceleration peaks).

Historical data are currently provided on vehicles as complex information, usually presented in graphics which could be more properly visualized on personal computers than on quite small screens – moreover when people's attention is devoted also to other tasks (mainly related to driving or mobility).

The challenge should be to cluster relevant information on consumptions in a way which is fast and effortless for users to access, while providing details "on-demand", pressing a dedicated button. What allows the user to shift from slow to fast thinking is to shift attention on loss/gain of km.

This refers to the Framing effect and to Loss aversion presented in the Prospect theory by Kahneman and Tversky (Kahneman & Tversky, 1979).

Concerning the framing effect, the "frame", that is the context in which the individual makes a choice, has a determining effect on the choice itself. In particular, the way a problem is formulated has an influence on the way the individual perceives the ''status quo'', with which respect s/he evaluates possible consequences of his/her actions.

Concerning the Loss aversion, for most people the motivation to avoid a loss is greater to the motivation to get a gain. This general psychological principle – which is probably linked to a surviving instinct – implies that the same decision can derive opposite choices if consequences are presented to a person as losses rather than lost gains.

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According to Kahneman's assumption that «losses loom greater than gains», the information presented in terms of losses should lead the user to go into further details with respect to information provided on the main page on energy consumptions.

The willing of the user to search for greater details could be reflected in the willing of pressing a dedicated button.

Based on considerations above and on Literature findings, a sketch of the future app was created, as reported in figures below (Figure 1).

Page 1

- Data which may be relevant to understand energy efficiency performance should be immediately available on the screen.
- Do not provide mean consumptions as the user may tend to remain in that range, even if s/he could perform better.
- Information on energy efficiency performance should not show previous values (e.g. average energy consumptions shown in a graph), but give a feedback on the energy performance itself.
- Feedback on energy efficiency performance (page 1) could be given so to induce the user to get more details (going to page 2).
- The presentation of energy consumptions values might have a greater impact on user's behaviour change if presents as kms lost (and not gained).
- A target value of energy efficiency should be presented to the user. This may be an "adaptive" information, which changes on the base of user's performance.
- Inserting user's performance in a social context may have an impact on individual consumptions and contribute to create a social learning dimension.
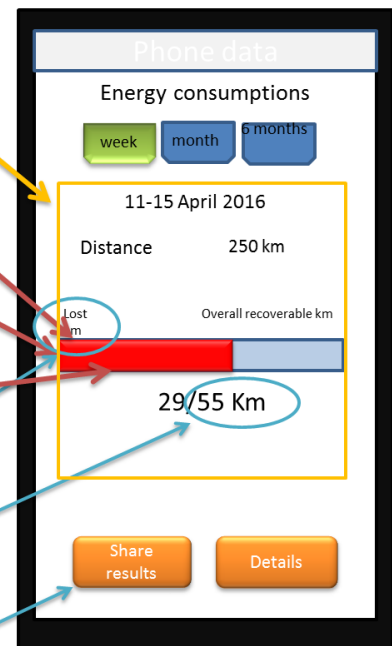
Figure 1 – Insights from Literature review included in the HMI concept (App, Page 1)

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Page 2

- Information on accelerating and decelerating behaviour should be given to the user.
- It should be made clear to the user that the goal under the use of the app is to increase his/her energy efficiency performance.
- A reference to performances of other users can have an impact on user's behaviour change.
- The use of a gamification approach can support and stimulate user's effort in improving his/her energy efficiency performance.
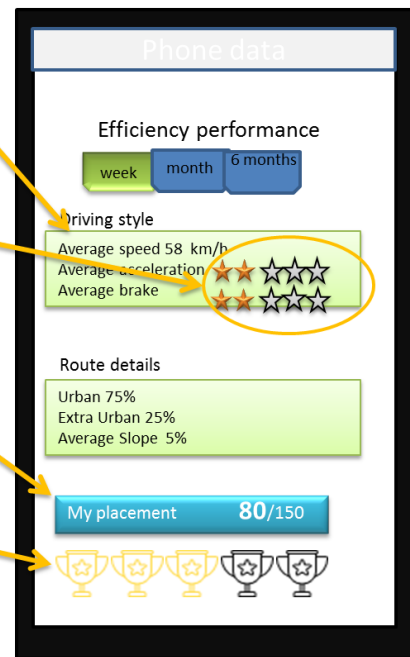
<u>Figure 2 -Insights from Literature review included in the HMI concept (App, Page 2)</u>

In page 2, Route details have been inserted based on factors that may affect the battery state of charge in electric vehicles.

Rezvanizanian et al. (Rezvanizanian, Huang, Chuan, & Lee, 2012) highlight that researchers previously summarized statistical results from field tests to offer some help in understanding battery performance (Huang, Tan, & He, 2011; Lee et al., 2011; Liaw & Dubarry, 2007; Montazeri-Gh, Fotouhi, & Naderpour, 2011). According to the literature, road type, traffic road slope, traffic and driving mode have major effects on battery state of charge and energy consumption during a trip.

3.1 Functionalities of the app

According to directions from Literature analysis and with reference to Kahneman's theories, functionalities of the app have been established.
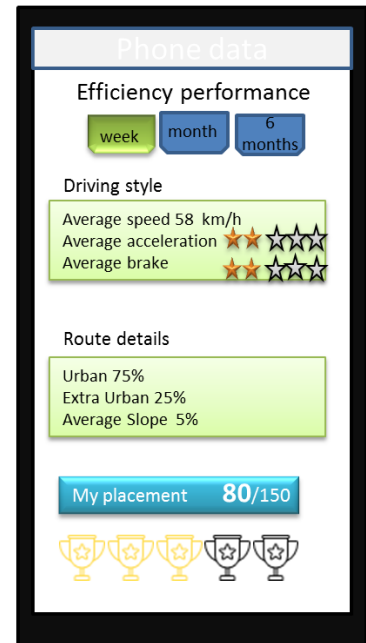
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Page 1   **Page 2**

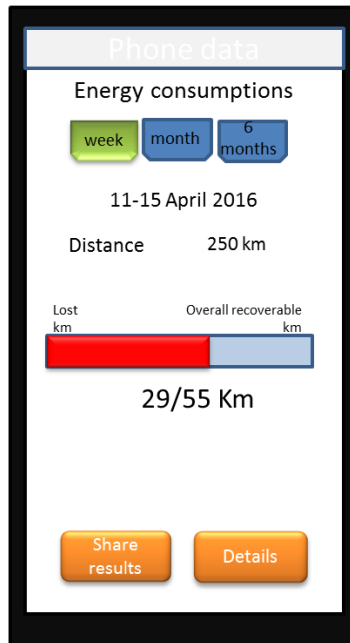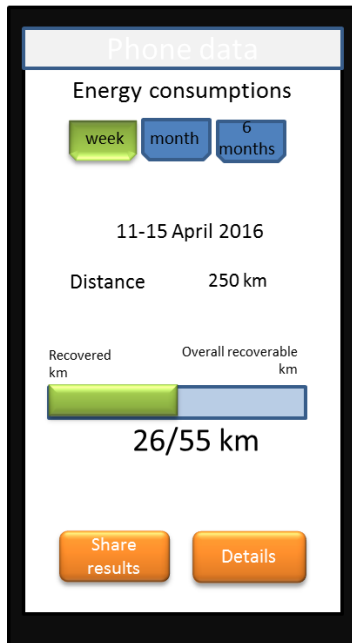Recovered kms   Lost kms

Figure 3 - Page 1 and 2 of the app

Page 1

At the top of the page, the user can choose a time period (last week/month/6 months) for which s/he desires to monitor (historical) energy consumptions. The selected period appears below the time selection buttons.

The total distance driven in the chosen period is showed right below in kilometres.

A bar graph shows the overall recoverable kilometres, which is the maximum energy (expressed in kilometres) that is possible to recover via e.g. energy braking. As explained by Clegg (Clegg, 1996), regenerative braking refers to a process in which a portion of the kinetic energy of the vehicle is stored by a short term storage system. Energy normally dissipated in the brakes is directed by a power transmission system to the energy store during deceleration. That energy is held until required again by the vehicle, whereby it is converted back into kinetic energy and used to accelerate the vehicle. As highlighted by Wager (Wager, 2012), an RBS (Regenerative Braking System) not just saves energy and improves efficiency but it also increases the vehicle range. This can help to reduce certain customers "range anxiety" a term used to describe the psychological state of mind of a driver unsure if they can reach their destination before the battery goes flat.

Due to the operating constraints of the drivetrain architecture and the varying nature of the braking conditions, it is unlikely that all the stored kinetic energy of the vehicle can be recovered during braking.

The maximum recoverable energy is calculated as a percentage over the Total driven kilometres: according to Henry et al. (Henry et al. 2001), the kinetic energy recovery of the electric propulsion system increases the driving range by 25 to 30%.

According to Kahneman's theories introduced above (D. Kahneman, 2011; Daniel Kahneman & Tversky, 1979; Tversky & Kahneman, 1974), in option 1 the recovered energy is represented as Lost kms (red bar), in option 2 is represented as Gained kms (green bar).

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Lost km are those kms that the user was not able to recover, even if s/he could.

At the bottom page, the user can: i) Share his/her results with other users; ii) Get details on his/her driving performance. If the user presses the button "Details", this is interpreted as his willing to understand where his/her driving behaviour is not correct (and, indirectly, the capacity of the HMI to conduct him/her towards the rational choice).

Page 2

Page 2 provides details on Energy consumptions.

The reference time period is reported from page 1 (last week/month/6 months).

Details are given on Driving style and Route details, as factors affecting the eco-driving performance.

In particular, as reported in Literature review, several authors (Strömberg & Karlsson, 2014; Birrell, S. A., Young, M. S., Weldon, 2013; El-Shawarby et al, 2005; Ericsson et al, 2001; Waters and Laker, 1980) point out that avoid excessive acceleration events have a beneficial impact on eco-driving. For this reason, average acceleration, deceleration and average speed have been included in the HMI.

The graphic layout was inspired by the SoA analysis of market eco-driving systems (reported in Annexes): in Driving style Average speed is provided as a numeric value (Km/h): the numeric value is inspired by details on energy consumptions provided in Tesla Model S. Average acceleration and braking are provided as in Ford electric 2012, but here they are provided as a score, referred to an optimum value. The better the user accelerates/brakes, the more stars s/he gets: this is linked to the concept of "award" a good behaviour as in Ford EcoMode.

Route details (percentage of urban/extra-urban routes and average slopes) have been inserted based on factors that may affect the battery state of charge in electric vehicles. Rezvanizanian et al. (Rezvanizanian, Huang, Chuan, & Lee, 2012) highlight that researchers previously summarized statistical results from field tests to offer some help in understanding battery performance (Huang, Tan, & He, 2011; Lee et al., 2011; Liaw & Dubarry, 2007; Montazeri-Gh, Fotouhi, & Naderpour, 2011). According to the literature, road type, traffic road slope, traffic and driving mode have major effects on battery state of charge and energy consumption during a trip.

Finally, based on results shared by other users, the driver can see his/her placement with respect to the performance of other users. The "cups" system used to award the best performance is inspired to Ford EcoMode.

3. *Heuristic evaluation of the HMI concept*

4.1 *Methodology*

A team of 5 evaluators has carried out the heuristic evaluation on static screens of the app (since the concept was at a preliminary stage).

The 5 evaluators were selected among experts in HMI and HF domains. In particular, 3 were ergonomists and 2 were UX (User Experience) designers.

Both groups had experience in the automotive domain and in the app domain. The average age was 37,20 years (std. dev. 5,63).

The heuristic evaluation was based on Usability heuristics in ISO 9241.

The evaluation has been carried out in different stages: i) Explanation of the scenario of use of the app (all the evaluators together); ii) Explanation of how to carry out the evaluation, as single experts (all the evaluators together); iii) Evaluation.

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Every evaluator had a printed copy of the app screens (Option 1 – Lost km - and 2 – Recovered km) and a pc, where they could display a digital copy of the Usability heuristics in ISO 9241 and fill in a table with their evaluation.

The evaluators were asked to look at the app screens (both Options) and to report their comments, violated heuristics, severity rating and any suggestions for improvement in a power point file – follow the guidelines explained above.

The evaluator was asked to associate a severity rating to each problem he/she found.

In particular the severity of a usability problem was evaluated as a combination of three factors: i) The frequency with which the problem occurs (Is it common or rare?); ii) The impact of the problem if it occurs (Will it be easy or difficult for the users to overcome?); iii) The persistence of the problem (Is it a one-time problem that users can overcome once they know about it or will users repeatedly be bothered by the problem?).

Violations were evaluated with the Sauro (2013) method: i) 1.MINOR: Causes some hesitation or slight irritation; ii) 2.MODERATE: Causes occasional task failure for some users; causes delays and moderate irritation; iii)3.CRITICAL: Leads to task failure. Causes user extreme irritation.

After single experts had carried out their evaluation, they were merged into a single report, reporting all of the comments, even if pointed out by only one evaluator.

4.2   Results

Evaluators provided suggestions for improving both page1 and page 2.

Concerning page 1 (for both versions LOST km & RECOVERED km), comments were about both graphical improvements and enhancement of functionalities. In particular, in order to increase the visibility of the most relevant information on the screen and to enhance the readability of the page, font size should be increased and there should be more contrast between text and background. Moreover, graphics should be used to differentiate areas, e.g. reference period for consumptions, covered distance and recovered/recoverable kms; or in order to show the relationship between covered distance and recovered/recoverable kms. Furthermore, the layout and content showed could dynamically adapt depending on the level of experience the user has with the app. Also, an indicator/icon of the performance (good or to be improved) could be added.

Also for page 2 (the same for both concepts), comments were provided for both graphical improvements and enhancement of functionalities. In particular, also in this case graphics could be used in order to group similar information, to differentiate areas with different information or to create links between different items. The use of infographics could be taken into account. Moreover, it was suggested to provide the user with a sort of training, both for the use of the app (e.g. to explain the user how calculations of recovered and recoverable kms are made) and for use information provided by the app in order to improve driving behaviour (e.g. how to optimize energy consumptions by improving driving style, for example reducing harsh braking). To this scope, pop-up messages or mini-tutorial could be helpful.

Finally, evaluators suggested to decrease levels of the interface and, consequently, to reduce the number of pages: for example, information on driving style, route details and My placement could be provided in page 1 or could be accessed via a menu.

4.   Outcomes from a co-design session

As mentioned by Sanders and Stappers (Sanders & Stappers, 2014), in the traditional design process, designers usually engage in making after the design opportunity has already been identified. Over the last 10 years, the focus has shifted to more varied forms and formats of

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making in the front end of the process. Today making has become an activity that both designers and co-designers can engage in during all phases of the process.

In the co-design session nine participants with different profiles were involved: not only three designers, but also three HMI and Human Factors experts, an app developer and two EV (electric vehicle) users with a long experience in Mobility issues.

The study was conceived to investigate empirically the benefits of using a creative idea generation process within a mobility context, where the provision of information via an app may have an impact on driving behaviour and energy consumptions. In particular, a co-design session was seen as a good opportunity to include relevant input from different categories involved in the creation and use of the app, specifically after re-design suggestions from the heuristic evaluation.

Three specific objectives were to: i) Understand the point of view of figures involved in the creation and use of the app; ii) Gain insights and explore possibilities for re-designing the app after the comments from the Heuristic Evaluation; iii) Understand what any proposed design project would mean for the people impacted – both as involved in the design and development process and as final users.

5.1   *Methodology*

As cited by Kane et al. (Kane, 2015), Co-design is a design approach that treats 'users' as 'experts of their own experience', allowing them to play a much larger role in design by involving them in creative and collaborative activities at various points across the design process, to develop knowledge, and to generate ideas and concepts (Sanders & Stappers, 2008). As pointed out by Björgvinsson, Co-design groups should contain a diverse range of participants in order to encourage learning and reflecting on each other's experiences (Björgvinsson, 2008). In fact, as highlighted by Mulder and Stappers, if the backgrounds, 'world view' and opinions of the participants are too homogenous, then any outcomes may be limited and even predictable (Mulder and Stappers, 2009). For this reason, 2 EV users have been involved, as well as 3 graphic designers, 3 HMI and HF experts and 1 app developer, in order to include different perspectives and to get an app which is usable by electric vehicle drivers.

Some weeks before the co-design session, 5 EV users were face-to-face interviewed: in about 30 minutes, they were invited to share their experience of use and behaviour when driving an electric vehicle. This allowed creating short stories (storyboard), which would have then been shared during the co-design session with all participants. This choice was based on considerations by Mulder and Stappers (Mulder&Stappers, 2009), who highlight the need to focus on the design of experiences rather than the design of individual products or services. Furthermore, this allowed understanding the whole experience of use of an electric vehicle. Storytelling, which is often used in co-design studies, was considered as an effective technique for capturing and sharing experiences (Battarbee 2003).

Some days before the co-design session, participants answered a background questionnaire. Questions regarded: i) Use of mobile apps; ii) Vehicle ownership and mobility needs; iii) Familiarity with Electric Vehicles; iv) In-vehicle energy consumptions monitoring.

The co-design session was divided into main different moments:

- Problem and context setting: Context and problem were described at the start of a collaborative session; also, core information on electric vehicles functioning were given;
- Story sharing: storyboards created in advance were read and commented by participants;

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- Problem understanding: participants were guided towards the understanding of the problem to be solved;
- Idea-generation: participants were invited to read a list of potential functions and to place them into Instrument cluster, page 1 and page 2 of the app: firstly this was done individually; then there was a group discussion and all the participants agreed on which function to place on the three areas.

5.2 Results

As a final outcome, participants produced a paper mock-up of the future app (page 1 and page 2) and pointed out main functions to be available in the instrument cluster, which should show complimentary information.

In particular, the Instrument cluster should report information on Instant data, having the objective to show Data useful while driving.

Main functions available on the Instrument cluster should be:

- Available range
- Instant speed
- Distance from destination
- Information on incoming slope/s, which can affect EV battery charge
- Choice of driving mode based on the objective.

Page 1 of the app should deal with Historical information, having the objective to: i) show driving performance ranking; ii) show how good performance could be rewarded with incentives.

Main function available on the app on page 1 should be:

- Historical data on acceleration/deceleration
- Driving performance ranking
- Information on incentives that driving behaviour has allowed
- Data sharing with other drivers.

Page 2 of the app should give Input for the future, providing information for Planning next trips and showing information on User profiling.

Main function available on the app on page 2 should be:

- User reputation (derived from feedback from other drivers)
- Estimation for next trip (user can cover a distance of "x" kms based on last performance).

Results from Heuristic analysis did not suggest major changes in the elements to be displayed on Page 1 and page 2, but the focus was on how the information was presented to users and how the user could learn from data in order to change his/her behaviour (e.g. use of infographics, add a training session or explain how calculations are made).

Participants to the co-design session went through information to be displayed and proposed not only a new configuration of information but also a "flow": considering the instrument cluster and the app as complimentary, the user should be able to use data to check his/her driving performance based on instant data (instrument cluster) and historical data (page 1 of the app) and infer how a future driving performance could be (page 2 of the app).

Finally, participants were not willing to display recovered versus recoverable energy, neither in form of lost nor gained kms. A major attention was paid to elements dealing with performance and a system of reward/punishment related to performance. Consequently, the application of Kahneman's theories to understand if the framing of an issue can have an impact on behaviour should take into account this preferences in order to understand which information could have a major impact on users' behaviour if presented with a different framing.

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5. *Conclusions*

Main outcomes from Literature analysis helped to find core elements to design the first version of the future app.

In particular, for page 1, based on the Literature review, the main choices were:

- To have data which may be relevant to understand energy efficiency performance immediately available on the screen (all of the elements in the centre of the interface).
- To not provide mean consumptions as the user may tend to remain in that range, even if s/he could perform better (only total distance and recovered kms over recoverable kms were presented);
- Information on energy efficiency performance did not show previous values (e.g. average energy consumptions showed in a graph), but gave a feedback on the energy performance itself (coloured bar representing lost/gained kms);
- The app gave a feedback on energy efficiency performance (page 1) so to induce the user to get more details, going to page 2 (bar reporting recovered kms over recoverable kms).
- To present energy consumptions values both as kms gained and lost: the core assumption of the work (to be verified) is that presenting them as lost kms might have a greater impact on user's behaviour change.
- To present a target value of energy efficiency to the user. This may be an "adaptive" information, which changes on the base of user's performance (recoverable kms against recovered kms).
- To have a "Share" button to inserting user's performance in a social context, since this may have an impact on individual consumptions and contribute creating a social learning dimension.

For page 2, main hints from Literature analysis were:

- To give information on accelerating and decelerating behaviour to the user (rank for average acceleration, deceleration, braking);
- To use a ranking system (e.g. cups or stars) in order to make clear to the user that the goal under the use of the app is to increase his/her energy efficiency performance;
- To display user's placement with reference to other users who had shared their driving performance data – since a reference to performances of other users can have an impact on user's behaviour change.
- To use a gamification approach to support and stimulate user's effort in improving his/her energy efficiency performance (e.g. ranking with stars and cups, user's placement.

The main outcome from the heuristic evaluation gave relevant hints to improve the app. In particular, experts suggested using graphics to differentiate a single piece information and/or information clusters or to show links between information.

The app could have a "training" section, which could help users to use the app or to improve the driving performance. As an alternative, the app could change dynamically, depending on the level of experience the user has with it.

Information on driving style, route details and users' placement could be displayed on page 1 or via a menu: this hint from evaluators has been also given during the co-design session.

The outcome from the co-design session has led to re-design the core elements of the app in a different way, complementing information on the instrument cluster.

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The main hint was to consider all of the three displays as complimentary to provide the user with an exhaustive overview of data needed before, during and post trip.

Consequently, the Instrument cluster should report information on Instant data, having the objective to show Data useful while driving;

On the other side, Page 1 of the app should deal with Historical information, having the objective to: i) show driving performance ranking; ii) show how good performance could be rewarded with incentives.

Finally, Page 2 of the app should give Input for the future, providing information for Planning next trips and showing information on User profiling.

In conclusion, participants preferred to display elements dealing with performance and a system of reward/punishment related to performance (and not recovered versus recoverable energy). This may imply a shift in the choice of what function should be framed in two different ways in order to verify the application of Kahneman's theories.

Acknowledgements

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