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ELECTRIC VEHICLE AND SUSTAINABLE MOBILITY: AN INNOVATIVE INTERFACE

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Abstract: The paper presents a concept of an innovative interaction structure for a digital electric vehicle (EV) dashboard. The structure connects interactions between vehicle, driver and traffic infrastructure, in order to help users driving in a conscious way, informing them about their performances and providing tools able to modify driving behaviour. Through the Systemic Design approach, it is possible to move from a quantitative configuration (set on consumption) to a new one set on resource optimization. The achievement is a new layout for the information visualization system designed for an electric vehicle able to communicate to the driver the environmental impact of its drive style.
Keywords: Eco design, visual communication, sustainable mobility, electric vehicle

1. INTRODUCTION

Environmental sustainability is often communicated through the use of stereotypes that happen in the same way in the matter of sustainable mobility, for example, introducing green washing languages within the dashboards of cars. The paradigm of sustainable mobility, however, goes far beyond the only and well-known need to reduce traffic and pollution, it recognizes the importance of the involvement of the population as a participating actor of the system. In order to do this design can increase the perception of the impact that everyday activity causes, through the interaction with tools that are part of the mobility-system.

The research investigates the use of smart interfaces in the automotive sector to give to the driver a new perception of the quality of his driving style.

Specifically, the concept for the dashboard of an electric car (EV) that will be described is able to show the best feasible driving behaviour through the organization of the available information on the car and the configuration of visual languages tailored to the characteristics of an electric vehicle.

2. ARCHITECTURE AND PERCEPTIONS OF THE ELECTRIC VEHICLE

The first electric vehicle was built in the nineteenth century, long before cars powered by an internal combustion engine. According to the CIVES (Italian Commission for Electric Road Vehicles) "if at the end of the century engineers had discovered an efficient way to store electricity, instead of large deposits of oil, maybe today we would have travelled with electric vehicles and internal combustion engines would have been considered only as a possible alternative". This did not happened also because until now some disadvantages have prevented the diffusion of EVs such as: the high sale cost (due to the low number of produced units); the low autonomy (due to the limited storage capacity of the batteries). Despite the disadvantages, the performances of an electric vehicle could be compatible with current mobility needs in urban conditions, 60% of the daily routes are less than 30 km and 75% of trips are less than 50 km [3].

From the constructive point of view, the necessary architecture for propelling of an EV can be summarized in three main components (Fig1):

- ✓ electric battery;
- ✓ engine;
- ✓ inverter.

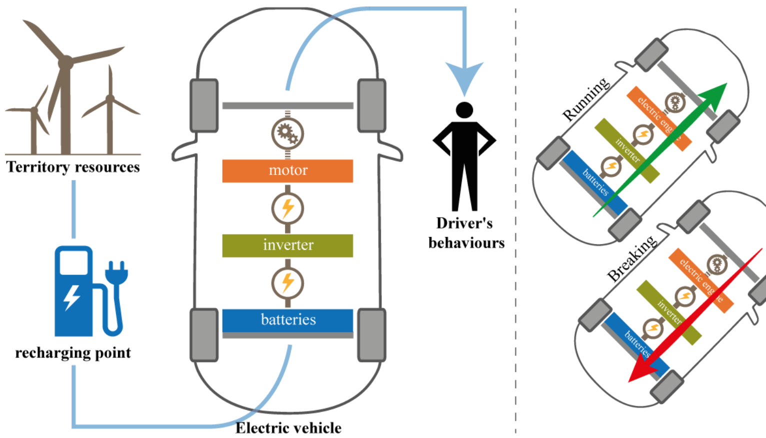

Figure 1 - EV architecture

To this day three ways to recharge electric vehicles were mainly developed:

- ✓ recharge from the electricity grid; the energy produced by different sources (hydroelectric, renewable sources, etc...), makes these vehicles suitable to be included in a context of sustainable mobility (programmed by local actors and based on the resources of the territory);
- ✓ battery replacement; modular discharged batteries could be replaced with preloaded ones in service stations, car dealers, department stores or dedicated parking spaces. The infrastructure should, in this case, comply with the new standards to ensure accessibility to the service;
- ✓ charging on the move; the great peculiarity of the EVs is that the batteries can be recharged while the vehicle is moving through regenerative braking.

3. DIFFERENCES BETWEEN CAR TYPOLOGIES

Electric cars show so many differences compared to cars with internal combustion engine (not only in the construction architecture), but there are features that make the two objects very similar especially in formal terms. In many cases, in fact, car manufacturers produced EVs rearranging models that were designed to host internal combustion engine, although human-machine interaction and visual languages should be different.

The communication model of the interface has not been changed instead, even if it is no longer consistent with the new structure. Clearly, as a matter of safety, some of these codes and the basic interactions with the main components, such as the steering wheel-pedals system, should not be changed in order to avoid driver's errors. In the electric vehicles, however, the language standardization is difficult to apply because every model of car embeds its own language and that one is constantly evolving.

The main difference between the two typologies of vehicle that can be capitalized derives from the possibility to recover energy through a correct driving behaviour.

If an endothermic engine car is a linear system in which the entire input fuel inserted in the vehicle is transformed into an output that cannot be reused, the electric car instead works in a different way. Based on the driver's conduct it is possible to obtain an advantage in terms of autonomy during the acceleration and the braking phase. This is a very important step forward from the cultural point of view, the driver, through his choices, can get a quantitative advantage of the use of the vehicle. It is therefore conceptually possible to think that the cars are becoming smart complex systems and they can provide an advantage if used properly.

Another difference is related to the modalities and the time of the recharging phase, that is however due to actual infrastructures. The density of service stations for endothermic engine vehicles is, in fact, very high. The situation of charging points across the territory is very different, they are insufficient even in the cities that have adopted an integrated service of car sharing that uses electric cars. The time of charging is then variable according to the kind of batteries, the charging point, the availability of energy and can vary between two to eight hours. The time parameter is very impacting if compared with that of a common internal combustion vehicle and if linked to the limited autonomy of several hundred kilometres.

In conclusion, the success of EVs depends on these three factors:

- ✓ larger number of charging points in the territory;
- ✓ faster charging times;
- ✓ larger mileage allowed by the autonomy of the vehicle.

Today the technological research is reaching very convincing results on the optimization of the products regarding all the three factors.

4. THE CONTROL PANELS INTERFACE, ANALYSIS OF THE COMPONENTS

A team of four experts in interaction design has made a hands-on analysis on twelve car to evaluate the interfaces present on electric and hybrid vehicles using an adapted version of the heuristics of Nielsen. The main focuses were, in fact, the visual languages, the communication aspects, the mental workload generated in the driver. A schematic map about interactions and patterns of distribution of the controls was created to better understand the critical issues about the use of the car. The analysed controls are Human Machine Interfaces across the board (Jef Raskin defines the interface as the way of doing something with an instrument, the actions to be performed and the manner in which the instrument provides answers [4]). The spotted problems are related to the dashboard of cars and HMI components were critically observed from the standpoint of ergonomics and position within the control panel.

The main criteria used for the analysis were:

- ✓ visibility, all the functional parts should be visible and should provide the correct message of what the driver is doing without distracting him;
- ✓ perceptibility, the ability to recognize the commands through the senses and past experiences;

- ✓ accessibility, parameter related to the size and the layout of the controls, the more the value is high the more the organization of the dashboard is balanced;
- ✓ clustering, it regulates the proximity of information and their grouping depending on the utility categories;
- ✓ sustainability communication, it is linked both to the environmental one and the mobility.

A large number of the analysed HMI were produced starting from the same model of car that has an endothermic engine; because of this the driver cannot perceive the potential of the electric vehicle considering that the code of visual and interactive language is set as an in traditional car. The gestures related to driving (regardless of the type of car) have been studied to highlight these issues. Putting all these analyses into a system has allowed the research team to limit the field of intervention, in order to: avoid the wrong approach of redesigning form and function of all the components (such as steering wheel and pedals), focus on innovative components. Many commands should, in fact, be designed from scratch or be redesigned to be compatible with an electric car.

5. HUMAN-VEHICLE INTERACTION ANALYSIS

The main commands in the interface have been examined using a scheme based on the cockpit of a city car. (Fig. 2) These items can be classified and can be simplified in areas of use, such as in Tönnis et al. [5], to establish a hierarchy of tasks.

The information is divided into:

- ✓ primary information, it is always visible and necessary while driving, in full compliance with the regulations;
- ✓ secondary information, it can be displayed on demand while driving and includes, for example, navigation and parts of the infotainment system;
- ✓ tertiary information, it can be acquired and displayed when the vehicle is not in motion or when the engine is off.

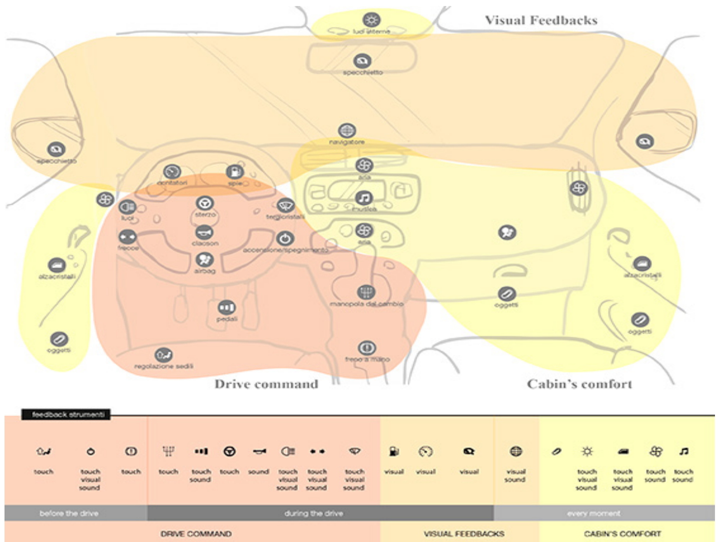

Figure 2 - Interaction schema

The actions involved in the interaction between man and the vehicle were mapped by dividing the needs of the driver in more specific tasks. In this way the interactive system can be displayed in depth. Thereafter, every action has been linked with its instrument of control on the dashboard.

The main actions managed through the HMI are:

- ✓ driving (control direction, speed up/slow down, know the needed information to control the vehicle);
- ✓ being aware of the information on the vehicle (vehicle status, maintenance, territorial context of driving);
- ✓ managing the comfort of the passenger compartment (temperature, interior lights, audio).

The analysis then considered the feedback, the fundamental component of the interaction that can transform the user experience from confusing and frustrating to efficient and pleasant.

6. DEFINITION OF THE ARCHETYPE OF INTERACTION

The development of the project has brought to redefine only some component of the car's dashboard. The development of the project has led the team to define only a selection of components of the car dashboard.

The design by components approach [5] pointed out and structured links and synergies between: vehicle components, driver's actions, the context of use.

An ideal ergonomic model (physical and cognitive) has been defined placing the human at the centre of the project, the aim is to design an archetypal interaction architecture (an essential structure on which both car designer and production engineers should work together). [6] The final schema is a tool that can be useful to develop concepts on eco-sustainability communication and to improve the perception of it.

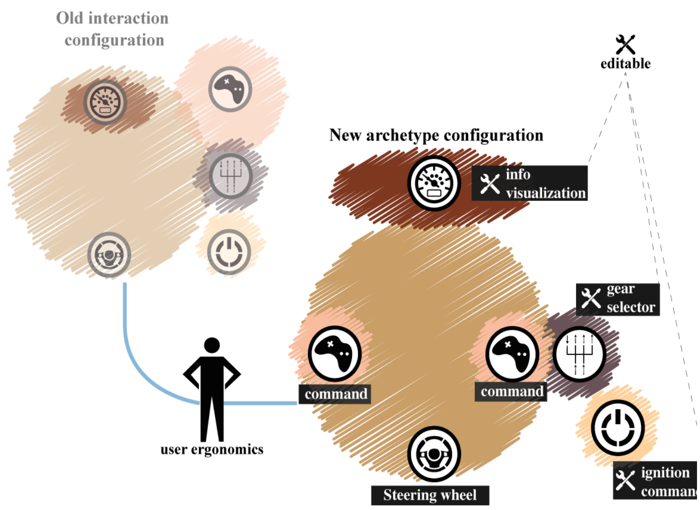

Figure 3 – Archetype of interaction

The designed components are: (fig 3)

- ✓ the ignition command;
- ✓ the gear selector;
- ✓ the info visualization.

6.1. The ignition command

The ignition phase of an EV is one of the most critical operations because the interaction is different compared to the one on common cars and the feedback is not easily understandable.

This kind of command is usually hidden behind the steering wheel, the new design, in order to give it the right visibility and reachability, envisions its position in the centre of the cockpit. In this way as the driver enters in the car he can perceive the command as the heart of the vehicle, the interaction starting point.

The main characteristics of the command should be:

- ✓ recalling the cultural gestures that the user does when he opens the car;
- ✓ having recognizable feedbacks;
- ✓ giving the possibility to the driver to choose the travel information he needs.

In the cognitive process the command form should resemble a key that activates the car after a physical gesture, in this way the driver succeeds in perceiving in correct way a proper feedback that symbolically looks like a force feedback. [4] (fig. 4)

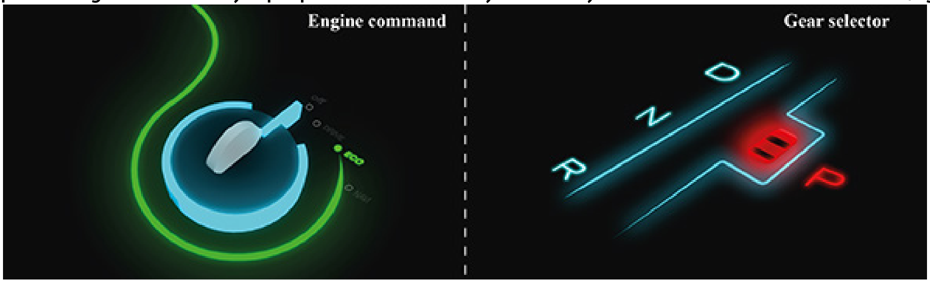

Figure 4 – The engine command / The gear selector

6.2. The gear selector

The gear selector is laterally located in comparison to the engine command; the reason why it has been positioned in this area is given by the gesture of the hand that moves from the engine command toward the steering wheel. The movement sets an interaction area and facilitates the correct completion of the tasks.

The gesture defines the form, the movements that go from the engine command to the steering wheel should be consequential and they should not confuse the driver. Its shape must be revised because it should be only used during the maneuver phase and not during the driving phase.

The shape has been designed carefully to: allow the use of the selector only during the maneuver phase and not during the driving phase; prevent the rest of the hand. The experience gained on cars with manual transmission could unconsciously lead, in fact, the driver to make wrong gestures.

6.3. Displays and info visualization

The project provides an optimal position for the

information inside the cockpit to avoid distractions to the pilot during the driving. On the tested cars the information were separated on many visualization areas; this forces the driver to divert attention from the road for a long time looking for the needed information and of course it creates distraction. From the safety point of view the info visualization in an H.D.D. (Head Down Display) mode or in an H.U.D. (Head Up Display) mode is different in terms of visualization and recognition speed. A study demonstrates that the H.U.D. mode can save one second on the driver reaction time (corresponding to a distance of 20 meters in braking, driving at 70 km/h). [8] This study completed from Dr. Young Ching Liu aimed to:

- ✓ define incidence of the positioning of the alarm signal in the answer times;
- ✓ define incidence of the displacement of the H.U.D. in the answer times;
- ✓ define the best and the worst position of the signal.

Moreover from the ergonomics point of view the central area within the visual field can be defined as the best one for the visualization of the signals because the interaction happens faster than on the edge of the screen.

For these reasons it was decided to: structure the information according to the taxonomy shown above, organize it in a hierarchical manner. This generated a display that is divided into three parts and visualized on a transparent screen placed in front of the driver. The section dedicated to the information strictly related to driving is positioned at the centre. On the lateral screens you can see the information related to secondary and customizable comfort of the passenger and the context of use.

On the lateral screens it is possible to visualize the secondary and customizable information related to the cabin comfort and the context of use.

In the central part it is possible to visualize:

- ✓ the speedometer;
- ✓ the selected gear;
- ✓ the total travel mileage;
- ✓ the partial travel mileage;
- ✓ the remaining autonomy.

Figure 5 - H.U.D.

The menus should be projected with interchangeable layers in base of the personalization of the user (for safety reasons the customization task should be allowed only when the vehicle is stopped), the chromatic choice has been dictated by different factors as the contrast with the colour of the road and legibility. (fig 5)

In this project to communicate with the driver the HMI should use a qualitative and not quantitative language; that means that in a complex scenario that includes EV and sustainable mobility the driver should perceive less information but qualitatively high ones. This information is acquired, processed and provided in order to be quickly perceived without wasting time to find, read and understand a large amount of complex data.

For this reason as cars will be more and more connected with the territory many information about the streets (ex. speed limit) could appear directly inside the cabin, not only on the road signals. The new designed speedometer is an example of qualitative language because it adjusts in real time its full scale with the maximum speed reachable on the road.

With regard to the sustainability communication in the automotive sector some good examples considered in the research are:

- ✓ Fiat Eco drive, a social network among the consumers for sharing data and experiences [9] ;
- ✓ the graphic language adopted by Nissan that creates in-time relationships between driver and vehicle with the insertion of elements that have proper life and that influence the driver behaviour [10];
- ✓ the communication campaign of Volkswagen Think Blue that promotes a proper use of the vehicle that is respectful of the environmental sustainability. [11]

Driving awareness brings advantages in addition to environmental sustainability: saving energy, saving money and increasing the available autonomy up to the next point of recharge. The design challenge is to give in real time a description of the correct use of the car starting from the driver's action.

In order to reach these goals the project refers to the car games scenario where it often appears an indicator of comparison called "ghost". In a game the ghost is sort of trailblazer, a depiction that precedes the car controlled from the player and that marks a trail to follow. From the project point of view, instead, it underlines the equilibrium, among brake and accelerator in order to provide the pilot the ability to self-adjust properly.

This component, called Co-pilot, gives the possibility to see the average use of the car with relative suggestions to improve it.

The Co-pilot corresponds to the thinking part of the vehicle and mediates the interaction with it, informing the driver on consumptions and recharge necessity (reducing the drive anxiety [12]).

When the navigator is activated, the co-pilot changes aspect making previsions about the residual autonomy on the established travel based on the driving style. (The more the autonomy value is near to the 0 the more the visualized information will be set on the possibility to recharge on the territory).

The information changes depending on the situations, it could be filtered by the user selecting the visualization patterns related to the engine command:

- ✓ DRIVE, information are totally suited on the driving;
- ✓ ECO, information is suited on the driving and the correct use of the vehicle;
- ✓ NAVI: information is suited on the driving, on the correct use of the vehicle and on the territory.

In addition to this information, in order to improve the interaction with the vehicle, two fluxes of light should guide the pilot to complete the tasks. This type of visual feedback is useful for:

- ✓ driving the interaction to the following task;
- ✓ giving visual feedback of the selected mode;
- ✓ giving visual feedback on the remaining battery autonomy.

The flux is a qualitative language and it suggests information creating an environment of interaction where the driver feels comfortable and confident with the vehicle (Fig. 6).

Figure 6 – Global overview of the project

7. NEXT STEPS

In the next phase of the research, the concept is going to be submitted to experimental analysis. During the user experience phase, other instruments (eye tracking, face to face interviews) will provide results that should be analysed by a multidisciplinary team (cognitive ergonomics specialists and interface designers) in order to give answer on the effective perception and understanding of the concept. The analysis will be set on:

- ✓ legibility of the information (also for small visual impairments);
- ✓ physics ergonomics of the command;
- ✓ values perception.

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