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The electric vehicle: A new driving experience involving specific skills and rules

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ABSTRACT

The arrival of the electric vehicle (EV) on the market is one consequence of government measures to improve air quality and reduce CO^2 emissions. However, the EV has specific properties of use associated with its limited range and relative silence compared to normal vehicles, influencing the mobility behaviours of drivers and requiring them to develop some new driving abilities. This paper examines the behavioural modifications brought about by daily use of an electric vehicle at three different levels of driving activity: strategic, tactical and operational. The study collected and analyzed the self-reported behaviours (via questionnaires and travels dairies) of 36 Parisian private drivers, each of whom drove for six months an electric MINI E prototype. The results of the study show that driving an EV requires a learning phase to acquire the skills and knowledge necessary to operate the vehicle. At the strategic level of driving, drivers take into account the restricted range of the EV, implement a daily charge process, and develop new behaviours related to trip planning. The study also examines driver behaviour at the tactical level, in terms of driver interactions with other road users to deal with the silent nature of the EV, and at the operational level of driving, in terms of braking behaviour to master the regenerative braking function of the EV. The paper discusses the interactions between these three levels of driving activity.

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1. Introduction

New international roadmaps for reducing CO_2 emissions are being accompanied by substantial financial investment in the development of sustainable transport. A large amount of funding has been allocated by private investors and governments to finance the development of renewable energy and multimodal transport systems that are energy-efficient and use cleaner fuels (MDB working group on sustainable transport progress report, 2015; United Nations, 2012). In this context, the electric vehicle (EV) is a relevant mode of transport: it is a practical alternative to conventionally fuelled vehicles if the production of electricity used is not polluting. This has resulted in the provision of government incentives (Valls, Royal, Sapin, Macron, & Eckert, 2014) to make the purchase of EVs more attractive (e.g., in France in 2015 a 6300 euros bonus increasing to 10,000 euros if associated with the destruction of an old diesel vehicle; against a 5000 euros bonus in 2011), and an increasingly varying range of EV models being offered by manufacturers to meet the specific needs of users, for both private and fleet vehicles (vehicles with 2 or 5 seats, varying range, etc.).

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Electric vehicles have specific properties, however, that are novel for drivers of conventionally fuelled vehicles. Drivers have to pay attention to the impact of the absence of vehicle noise at low speed (Cocron & Krems, 2013; Sandberg, Goubert, & Mioduszewski, 2010). They have to master the regenerative braking function that uses deceleration to charge the vehicle (Cocron et al., 2013). Drivers have also to deal with the limited range of the car and to plan for the charging of the electric batteries (Franke, Neumann, Bühler, Cocron, & Krems, 2012). Moreover, previous research shows that people are not yet used to managing electricity in the vehicle. They lack knowledge about electricity and batteries, and that affects their understanding of the EV and the best way to interact with it (Caperello & Kurani, 2012; Cocron et al., 2011; Strömberg et al., 2011). Given these issues, and for the successful deployment of EVs, it is important to understand to what extent driving activity is modified by the specific features of the EV: that is, what behaviours arise in order to interact with it efficiently from an economical and safe point of view. We review briefly below relevant research findings in this area.

1.1. Driving tasks

The model of the driving task proposed by Michon (1978, 1985); see also Van der Molen and Bötticher (1988)) provides an efficient framework for describing the specific driving activity engaged in by drivers during daily use of the EV. Michon modeled driving as a hierarchical categorisation of all the tasks the driver must make throughout a trip. The model is useful in classifying new tasks that derive from the use of EV technology and changes to existing tasks, as well as the behaviours implemented to manage them.

In Michon's model (1978, 1985), three main levels of tasks are differentiated. At the *strategic* level the tasks performed relate to trip planning. Decisions concern the choice of a relevant route to reach a destination according to constraints such as the time the driver has, the amount of time allocated to the trip, and the choice of the vehicle. Here, the driver might evaluate the most comfortable and quickest route (based on roadwork, traffic jams, etc.), and any potentially dangerous situations (driving at night, driving in rain) (Wilde, 1982; Wilde, Gerszke, & Paulozza, 1998). There is the possibility at the strategic level that driving an electric car will change the way trips are planned because of its limited range. In current generation EVs, range is very restricted compared to that of a conventionally fuelled vehicle and energy becomes a daily factor to manage, as trips are limited in terms of distance. New strategic tasks are thus generated: drivers will have to take greater account of their travel itineraries, of unforeseen events, of the location of charge stations, and so on. The few studies that have explored feedback from long-term EV users confirm that daily use leads to the emergence of new behaviours. This is not immediate and requires a learning process, during which drivers understand how the EV range fits into their lifestyle, and adapt their trip planning accordingly. Generally, it seems that drivers modify their driving behaviours, such as speed and trip routes, adopt safe driving strategies to avoid critical range situations (Franke, Bühler, Cocron, Neumann, & Krems, 2012; Pichelmann, Franke, & Krems, 2013; Rolim, Gonçalves, Farias, & Rodrigues, 2012; Woodjack et al., 2012) and develop a charging routine (Bunce, Harris, & Burgess, 2014). Finally, the *strategic* level is modified for some drivers by the emergence of more trips done with the EV (Rolim et al., 2012). Thus, there is evidence that daily use of an EV brings about some new driving behaviours at the strategic level of driving.

Michon's model includes other driving tasks distributed across two additional levels that can also be modified by the management of the specific features of the EV. At the *tactical* level, the driver must analyze in real time modifications to the traffic environment and adapt actual driving behaviours and his/her interactions with other road users according to circumstances; the driver must plan actions under specific situational contexts. When driving an electric car, task activity at this level would be amplified by the need to pay more attention to interactions with pedestrians. In France, for example, pedestrians are not accustomed to interacting with silent vehicles: there are still few electric cars on the road (only 42,000 EVs were registered in France between 2011 and 2014; cf. AVERE France, 2015), and bicycles make up only 2.6% of all trips made by the French (according to the last national study on French mobility, Revue du CGDD, 2010). Because people detect several operating conditions of cars by visual and auditory cues, the lack of noise at low speeds could create new safety issues. Experiments show that the time from the first detection of a target vehicle to the instant the vehicle passes the pedestrian location is significantly decreased with an EV (Czuka, Conter, & Wehr, 2014; Garay-Vega, Hastings, Pollard, Zuschlag, & Stearns, 2010), which impacts on the ability of pedestrians to travel safely. Driving EVs at the tactical level will therefore have to take account of the silent nature of the EV, obliging the driver to adopt more attentive behaviours to other road users.

Finally, the most basic level of Michon's (1978, 1985) model of driving is the *operational* level, which relates to control of the stability of the vehicle (control of the brake and accelerator, lateral control, and so on). In driving an electric car, users in France will have to get used to driving with only accelerator and brake pedals: in France, the percentage of automatic vehicles in the vehicle fleet, with only two pedals, is marginal; manual transmission vehicles are the norm (in 2014 automatic vehicles represented less than 15% of the cars sold; cf. Comité des Constructeurs Français d'Automobiles, 2014). The presence of a feature absent in conventional cars -regenerative braking- adds an additional task at the operational level of driving: in some vehicles the car brakes when the driver releases pressure on the accelerator pedal (Vilimek, Keinath, & Schwals, 2012) to enable a certain amount of kinetic energy to be recovered and transferred to the battery. This new control mechanism, regenerative braking, offers new opportunities for energy management behaviour compared to conventional cars. However, it may impact on the operational activities of the driver who needs time to become familiarized with its operation (Cocron et al., 2013).

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