Transport Research Arena 2014, Paris

The impacts of electric cars on road safety: Insights from a real-world driving study

Philippe Nitsche[a*], Michael Aleksa[a], Martin Winkelbauer[b], Marko Harnisch[a], Michael Kammer[a]

[a]*AIT Austrian Institute of Technology, Vienna, Austria*
[b]*Austrian Road Safety Board (KFV), Vienna, Austria*

Abstract

In this paper, we explore the differences in vehicle dynamics and drivers' behaviour between electric cars (e-cars) and conventional cars with combustion engine. Our research aimed at revealing potential safety risks due to a higher e-car penetration, e.g. incidents or conflicts with other road users that primarily occur with e-cars involved. To do this, we conducted a real-world driving study with 90 participants on a pre-defined route. Each participant had to complete the route with an electric as well as a similar conventional car that both recorded video, GPS data and 3D accelerations. Our results show that the effects of an electric engine on "non-extreme" vehicle dynamics are negligibly low compared to other factors such as transmission type. Surprisingly high decelerations were measured during the e-car's recuperation phases, which might lead to risks for follow-up drivers. The analysis of questionnaires showed that the participants felt safe and got used to the e-car quickly.

Keywords: Electric cars; road safety; traffic accidents; e-cars; vehicle dynamics; driving study; driver behaviour.

Résumé

Dans cet article, nous explorons les différences en matière de dynamique des véhicules et de comportement du conducteur, entre les voitures électriques (e-cars) et les voitures conventionnelles à moteur à combustion. Nos travaux visent à évaluer les risques de sécurité potentiels dus à une pénétration plus élevée des e-cars, tels que des incidents ou conflits avec d'autres usagers de la route impliquant en premier lieu des e-cars. À cet effet, nous avons conduit une étude en conditions réelles de conduite impliquant 90 participants sur un trajet défini par avance. Chaque participant a parcouru le trajet avec une voiture électrique et une voiture conventionnelle. Lors des deux trajets, des données vidéo, GPS et les accélérations 3D ont été enregistrées. Les résultats montrent que les effets d'un moteur électrique sur des trajets "non extremes" sont négligeables, comparés aux effets d'autres facteurs tels que le type de transmission. Étonnamment, de fortes décélérations ont été enregistrées lors de la phase de récupération du moteur, qui pourraient représenter un risque pour les conducteurs situés derrière le véhicule. L'analyse de questionnaires remplis par les participants montre qu'ils se sont sentis en sécurité dans la voiture électrique et qu'ils se sont rapidement accoutumés à sa conduite.

Mots-clé: Voitures électriques; sécurité routière; accidents routiers; e-cars; dynamique de vehicule; étude de conduite routière; comportement conducteur

---

[*] Corresponding author, Tel.: +43 50550 6517, fax: +43 50550 6599,
E-mail address: philippe.nitsche@ait.ac.at

1. Introduction

In recent years, electric cars (e-cars) have been given increased attention due to rising costs of petrol-based fuels and higher emission awareness. E-cars are a promising technology for reducing environmental effects of road transport (cf. Hawkins, Singh, Majeau-Bette, Guillawne, & Hammer Stromman, 2012; Kloess, 2011), but they are not yet competitive with conventional vehicle technology. Uncertainties regarding costs, performance, range and infrastructure requirements such as electricity supply held back a wide spread on the vehicle market (Santini, 2011). However, it is expected that fully-electric car sales will constantly grow, especially for the purpose of short urban travelling (Singh, 2010). In general, electrification is going to play an important role in city planning as well as public and individual transport solutions.

In order to pave the way for integrating e-cars in modern transport systems, road safety issues must be taken into account. On the one hand, electric engines are quiet, which leads to a lower perceptibility for vulnerable road users, particularly at low speeds (cf. Garay-Vega, Hastings, Pollard, Zuschlag, & Stearns, 2010; Morgan, Morris, Muirhead, Walter, & Martin, 2011; Pollard et al., 2012; Sandberg, Goubert, & Mioduszewski, 2010; Wall Emerson, Naghshineh, Hapeman, & Wiener, 2011). On the other hand, e-cars could show different vehicle dynamics due to a higher engine torque, different mass distribution and energy recuperation techniques.

While field operational tests (FOTs) are considered a reliable method for evaluating a new technology, most research on electric vehicles is based on questionnaires, interviews and surveys to find out various changes in driver behaviour characteristics (Carroll, 2010, 2011; Jabeen, Olaru, Smith, Braunl, & Speidel, 2012). Since little specific research on safety of e-cars has been conducted so far, the following research questions are still outstanding: Do drivers change their behaviour in e-cars? What are the differences in driving dynamics between e-cars and conventional cars? Which influence does the recuperation have on driving and braking behaviour?

In this paper, we explore the differences in vehicle dynamics and drivers' behaviour between personal e-cars and conventional personal cars with a combustion engine (c-cars). Our research aimed at revealing potential safety risks due to a higher e-car penetration, e.g. incidents or conflicts with other road users that primarily occur with e-cars involved. To this end, we conducted a real-world driving study with 90 participants on a pre-defined route in the area of Vienna, Austria. Since we focused on analysing short-term behaviour, the route took approximately one hour. Each participant had to complete the route with an electric as well as a conventional car of an equivalent class. Besides video recordings from a position similar to the drivers' point of view, we collected 3D accelerometer and GPS data with smartphones. We aimed at developing a data acquisition and analysis system, which does not distract drivers and which is easy to implement in various vehicles. Our analysis focused on pre-defined regions of interest located on the test route, including curves, roundabouts, intersections as well as pedestrian and railway crossings. Additionally, findings were derived from questionnaires that were completed by each participant and included subjective information about safety perception and driving style, amongst other.

The paper is organized as follows: Section 2 describes the methodology followed in the project and explains the driving study design, our test route, vehicles used and our data acquisition system. In Section 3, we present our data analyses, where we evaluate driving dynamics of e-cars compared to c-cars, video recordings and questionnaires. Based on that, results are derived in Section 4 with special emphasis on road safety impacts. The paper draws overall conclusions in Section 5.

2. Methodology

2.1. Test route and vehicles

The driving study was performed by using an experimental design, i.e. the test drivers had to complete a predefined route with an e-car and a c-car, respectively. It was decided that the route should facilitate assessment of the following situations:

- Start-up behaviour at intersections (regulated / unregulated)
- Brake behaviour at intersections (regulated / unregulated)
- Behaviour while turning left on an intersection with contraflow
- Behaviour in a roundabout

- Behaviour at crosswalks
- Behaviour in curves

This required the route to include points of interest (POIs) such as roundabouts, regulated and unregulated crosswalks, railroad crossings, curves with varying radii as well as intersections with contraflow allowing left turns. Furthermore, the route and especially its distance had to be selected according to the limited range of e-cars, which currently is between 100 and 120 km. To organize the test drives efficiently and timely, we conducted up to three e-car test drives per day. Hence, loading times of the battery had to be taken into account.

The final test route was selected according to the requirements above (see Figure 1). It included mainly urban and rural roads, had a distance of approximately 43 km and took 70 minutes to complete. A portable navigation device (Garmin Nüvi 2445) was installed in the vehicles to guide the drivers along the route. The route was designed as a circuit and several waypoints were defined and stored in the device. Map as well as voice guidance were activated. No other vehicle passengers were intended to go with the driver.

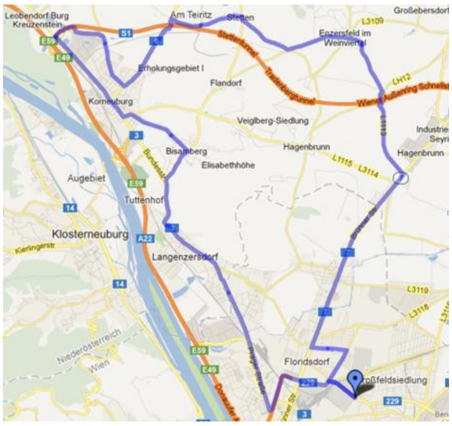

Figure 1: Test route in Google Maps (North-East of Vienna)

We aimed at using two e-cars–one subcompact and one midsize class vehicle–for a broader evaluation of driving dynamics. Two c-cars equivalent to the respective e-car's class were rented for the test drive period. Figure 2 shows the two pairs of vehicles used for the driving studies. While the Hyundai i10 is operated with a manual gearbox, the Renault Mégane has an automatic transmission. The Mitsubishi i-MiEV allows the driver to choose between three recuperation modes (high, medium, low), from which we set the medium one, i.e. optimal braking effect for most driving situation.

Figure 2: Test vehicles used: Left: Mitsubishi i-MiEV (e-car) and Hyundai i10 (c-car), right: and Renault Fluence Z.E. (e-car) and Renault Mégane Combi (c-car)

2.2. Selection and recruiting of drivers

The test subjects were primarily selected from AIT's and KFV's subject database. In addition, some of the test drivers were recruited among AIT's and KFV's employees, where only people were considered who had no link to the project and no relation to the topic. Additional methods were used as typical for such exercises, i.e. word-of-mouth advertising, snowball e-mailing, etc. Due to the experimental design, sociodemographic representativeness of the sample was not an urgent necessity, however, it was considered as good as possible.

In total, there were 97 test drives executed. Seven of the subjects were involved twice, i.e. once with the subcompact and once with the mid-size pair of vehicles. 15 of the subjects were female. 39 of the subjects were between 20 and 29 years of age, 3 were between 50 and 59 years old, 5 were above 60. Only 4 of the subjects declared to drive a car less than "a couple of times a month". Half of the subjects considered themselves "very experienced" as drivers, only six declared to be "hardly experienced in driving". Concerning their driving style, 6 of the drivers characterized themselves driving "very sporty", 9 drive "not sporty at all". Hence, the vast majority drives moderately.

2.3. Driving study procedure

The test drives were performed from spring until summer 2012. During one test day, on average three test persons drove the route with a c-car as well as with an e-car. Additionally, short questionnaires were completed: Before the test drive, the individual estimation of each test person of his own driving style, his driving experience with c-cars, the frequency of using the own car and of the experience with e-cars was asked. After completing the test route, another questionnaire was given to the test drivers in order to identify differences regarding to driving situations and conflicts with other road users (e.g. pedestrian, cyclist).
Every subject had to drive the test route once with an e-car and next time with the comparable c-car. To reduce adaptation effects and to minimize possible systematic errors, the order for the first trip regarding to the vehicle was varied: half of the test persons drove by a c-car first and the other half first by an e-car.

2.4. Data acquisition system

Most data acquisition systems used in recent (naturalistic) driving studies are complex and require a large amount of different data, i.e. their implementation is complicated and not easily transferable to other vehicles. Hence, our aim was to set up the hardware as compact and flexible as possible. A requirement analysis resulted in the following minimum set of data to be collected in the driving study: 1) GPS position, heading and speed, 2) video from a position similar to the drivers' point of view, 3) Translatory and rotational motion of the car.

All of these data sources can be collected with modern smartphones. Therefore, we decided to use two state-of-the-art smartphones with integrated GPS receiver, HD video and motion sensing technology (accelerometer, gyroscope, magnetometer) in combination with solid mounts (see Figure 3). One smartphone was mounted on the windshield and used for recording GPS data and video with an attachable fish-eye lens to widen the viewing angle. The other one was solely used for motion sensor readings, i.e. longitudinal, lateral and vertical acceleration/deceleration, roll, pitch and yaw rate. It was rigidly fixed on the adjustment rail of the front passenger seat in order to avoid vibrations and displacements that may occur on a windshield mount. We also chose this position to place the device close to the central longitudinal axis of the vehicles for more accurate driving dynamics measurements. Both devices were connected via WiFi and time synchronized.

Figure 3: Smartphone-based data acquisition with one phone mounted on the windshield to record GPS and video (left) and a second one fixed on the front passenger seat to measure 3D acceleration (right)

For data collection and analysis, we developed dedicated software tools. GPS data, motion sensor readings and videos are stored in separate files handled by our data collection app developed for Android smartphones. It also handles the data connection between the two smartphones and synchronizes timestamps.

We developed a graphical user interface (GUI) in C# for visualizing the video, GPS location, accelerometer readings and POIs (see Figure 4). It was used for analysing and annotating driver behaviour, incidents and external influences such as other vehicles, obstacles or weather condition (see also Section 3.2). All other numerical data analyses were performed in Python (using the Numpy and Scipy libraries).

Figure 4: Software tool for data visualization and annotation

3. Data analysis

3.1. Evaluation of driving dynamics

Electric engines provide a roughly constant torque regardless of revolution speed. In addition, e-cars do not use a manual gear shift. This results in different driving dynamics when an e-car is brought up to speed in comparison to a c-car since there is no disruption of forward-movement (i.e. no gear changes) and the flat curve of torque of an electric engine facilitates a continuous, fast acceleration.

There are also differences to be expected when the car is brought to a standstill. In order to increase the range of e-cars, the energy of the car's movement is not wasted by using normal wheel brakes (and thus converted into heat) but instead partially converted back into electric energy. This process called recuperation uses the engine as generator and the created energy is employed to charge accumulators. This could result in higher decelerations than conventional engine brakes of c-cars.

3.1.1. Acceleration and deceleration behaviour

The longitudinal acceleration in the period of 10 seconds before and after a standstill, i.e. stop of the car provides an insight into the acceleration and braking behaviour of the car-driver system. Due to the large amount of driving data, this required an automatic identification of standstills. GPS data was found to be too imprecise to recognize standstills reliably. For this purpose, we developed an algorithm primarily based on deceleration and acceleration analyses. Figure 5a is based on driving data of all standstills recognized by this procedure, grouped by vehicle class (mid-size –Fluence and Mégane, subcompact –i-MiEV and i10). In total, 3325 standstills were detected. The thin lines in the figure show the lower and upper quartile (0.25 and 0.75 quantile respectively) at each point of time. These quartile-lines were constructed as follows: First, the longitudinal acceleration data was superimposed according to timestamps, which use the standstill as origin (time 0). Then, for each point of time, the lower and upper quartiles were computed individually. In a last step, these points were connected by a line. Hence, the quantile curves must be interpreted carefully and do not correspond to actual longitudinal acceleration curves, which occur in reality.

In Figure 5a it is clearly visible that e-cars (blue lines) exhibit a smooth acceleration and braking behaviour, compared to a rougher curve for c-cars (red lines). Both e-cars show a lower maximum acceleration than the c-cars. The left part of the curves for e-cars (braking to standstill) appears constant around -1 m/s², which can be explained by the recuperation technique when releasing the accelerator pedal. Contrarily, c-cars show a more varying curve due to manual braking of the drivers. Note that the data for the Renault Mégane does not differ significantly from those of e-cars. While the manual gear change 2 to 5 seconds after starting the forward movement of drivers of the i10 is very distinct, the sudden drop in acceleration during a change of gear is not visible at all for the Mégane. This indicates that the automatic transmission changes gears much faster and/or smoother than the human drivers.

To support the evaluation results above, Figure 5b depicts the entire accelerometer data set for each car used in the study, excluding standstill periods. The blue density plots (e-cars) clearly indicate the recuperation phenomena at approximately -1 m/s², whereas the red plots (c-cars) have a higher density closer to zero. For the Hyundai i10 (manual transmission), this peak is more pronounced compared to the automatic transmission of the Renault Mégane. In contrast to the deceleration phases, minor differences can be observed in the acceleration behaviour. The density plot for the i10 indicates the manual gear shifts at approximately+1.3 m/s².

In summary, these graphs indicate that the longitudinal acceleration behaviour of e-cars does not differ drastically from c-cars.

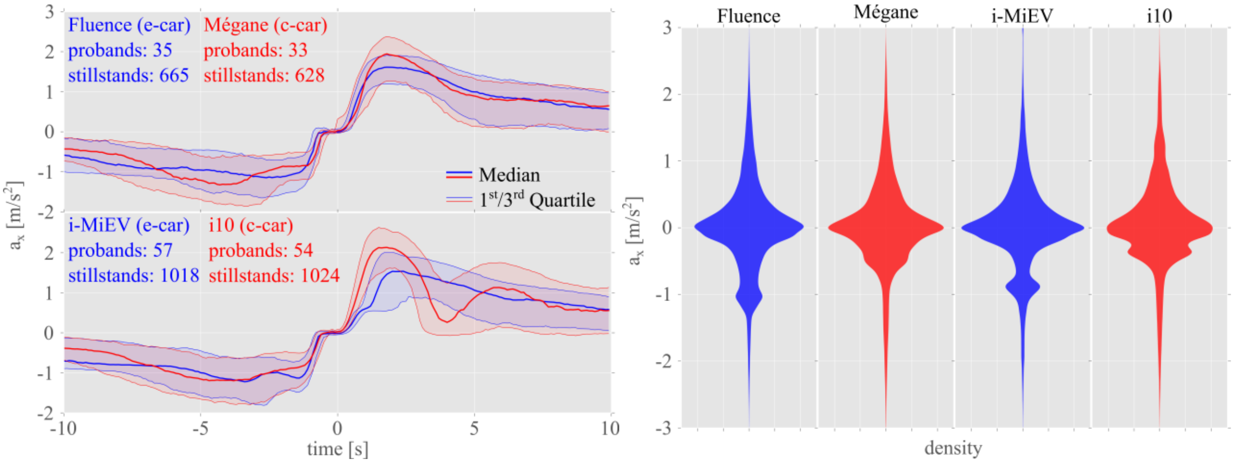

Figure 5 (a) Longitudinal acceleration data 10 seconds before and after a standstill for each car, grouped by vehicle class; (b) Symmetric density plots of longitudinal acceleration data, for each car

3.1.2. Curves and roundabouts

We evaluated curves and roundabout individually to avoid issues with differing road parameters such as curve radius, speed limits or sight limits. Predefined POIs along the route were located using GPS data. To compensate for differing velocities while driving through curves and roundabouts, we normalized their length to the value 1. For each drive and POI, the data was thus brought to a common interval.

Figure 6a shows the lateral acceleration data exemplary for a curve driven with the subcompact cars, the i-MiEV and i10. In contrast to the earlier findings, there are virtually no differences visible in the accelerometer or GPS speed data. The situation is similar for roundabouts, such as the exemplary one shown in Figure 6b. Note that minor inaccuracies in the curves may also stem from the rather small sample sizes, which are caused by only including data where the base conditions for the drivers were comparable (e.g. no car in front while passing through the curve). This leads to the impression, that the drivers chose almost equal speeds and trajectories while driving in a curve or roundabout, regardless of the engine type.

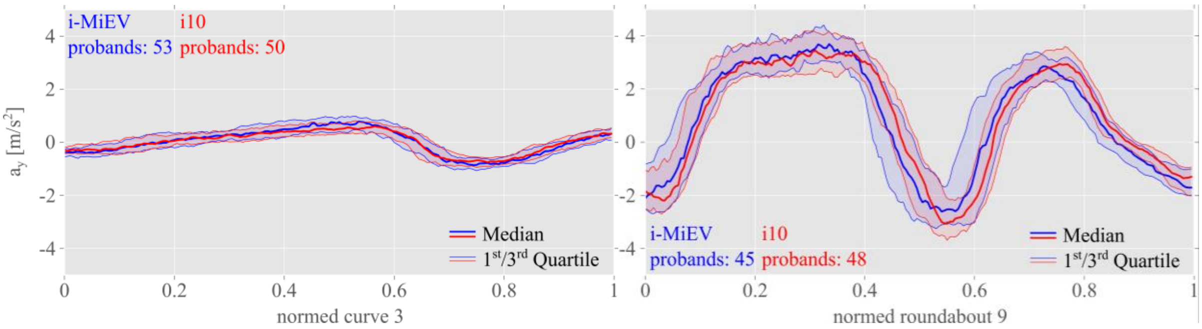

Figure 6: Evaluation of lateral acceleration in an (a) exemplary curve and (b) roundabout driven with the subcompact vehicle pair

3.1.3. Detecting incidents beyond the points of interest

We used the driving dynamics data to find potential driving conflicts. This procedure was necessary to identify relevant video sequences. First, deceleration events exceeding 0.6g for at least 0.5 s were selected. This resulted in about 70 events in total, of which more than half were created by only two subjects. Hence, the strategy had to be changed: Deceleration events below 1.5 m/s² were excluded in order not to consider recuperation. Among the remaining deceleration events, the 0.05-quantile peak deceleration of each driver was computed, multiplied by a factor of 1.5, which was iteratively determined. By doing so, we set the deceleration threshold individually for each driver. Further results based on these triggers are presented in Section 3.2, especially Table 1.

3.2. Evaluation of video data

Video data treatment included three activities. First, a simple video annotation procedure was carried out in order to enrich the existing data on driving dynamics. Second and third, both the situation, which showed excessive values in driving dynamics and the situations where subjects indicated peculiar circumstances, were reviewed.

In total, 102 POIs were identified along the route. Those consisted of intersections with or without traffic lights, roundabouts, crosswalks, curves, at-level railroad crossings and some other. By using GPS data for identifying beginning and end of passing the POIs, the respective video data streams were marked automatically. The annotation GUI was used to indicate relevant circumstances in the data stream, such as:

- Stopping ahead of site
- Other vehicle ahead on approach, on departure or in a curve
- Pedestrians present at crosswalks
- Bicycle riders present on right turn
- Other car crossing on right turn
- Oncoming vehicles on left turn
- etc.

These annotations were not primarily subject to research per se, they were necessary prerequisites to facilitate research on other questions. For instance, acceleration events where the driver could not accelerate freely due to a car in front of him should be excluded.

We are glad being able to report that there were no accidents during the test drives. Nevertheless, there were other events as shown in Table 1. A “triggered event” was an event where either data or driver triggered, but the video did not show any unusual issue. “Episode” is defined as a situation with unusual behaviour of the driver (e.g. speeding, violation of priority rules) but neither accident nor near-crash. “Near miss” is defined as a situation, where a sudden manoeuvre was executed in order to avoid a collision.

Table 1: Number of events by category, trigger and vehicle

Trigger	Category	Number of observations				
		i-MiEV (e-car)	Fluence (e-car)	i10 (c-car)	Mégane (c-car)	Total
Driver	Triggered event	2	3	2	0	7
	Episode	3	3	1	3	10
	Near Miss	2	2	2	0	6
Data	Triggered event	9	2	8	6	25
	Episode	2	2	3	3	10
	Near Miss	0	1	3	1	5

After video assessment of the events found by the procedure as described in Section 3.1.3, most of the events were found to be normal braking manoeuvres, triggered by a car ahead, by a red light or a stop sign. However, five near-crashes were observed:

- Braking behind a bus surprisingly leaving a stop
- Braking to avoid a collision with an oncoming car, which swerved around a truck that drove out of a gateway on the opposite side of the road (left side for the test driver)
- Braking from 45 km/h to full stop in a 30 km/h area behind a lead vehicle, who gives way to a prioritized car coming from the right
- A driver passes an emergency vehicle parking in his lane, another vehicle came out of the blind area
- Oncoming car with unpredictable trajectory, test driver applied the brake just for safety reasons.

None of the events could be qualified being typical phenomena related to the nature of the engine.

3.3. Evaluation of questionnaires

During the recruitment phase, some information was collected to increase the representativeness of the sample. In addition, a short questionnaire was provided before the test drive (see Section 2.3) as well as after each pair of drives (once with one of the two e-cars and once with the respective c-car). These were partially adapted from other projects (Lenz & Aytan, 2012) in order to collect additional data on attitudes towards e-mobility. The major part of the questionnaire was particularly designed for this study and addressed experiences during the test drives.

Almost three quarters (74%) of the subjects did not have any practical experience with e-cars before doing their test drive. 16% had driven an e-car once before, 8% a couple of times. Only 2 of the subjects were experienced e-car-drivers. After the drive, 97% had a good or very good impression about driving an e-car in general. It is also a vast majority, who got familiar with the test vehicles quickly. It was only the Hyundai i10, which 19% of the subjects got “rather slowly” familiar with. This car, in addition to the internal combustion engine, had manual gear shift. 71 of the 90 subject felt a difference in driving between e-cars and c-cars. The answers to this question were somewhat incoherent, when subjects first indicated having experienced no differences and then explained about differences in the prose text of the next question. In such cases, we corrected the value for the first question. If subjects indicate differences, they mostly refer to lower perceptibility of e-cars compared to c-cars.

4. Results

The driving study involving 90 subjects, including almost 200 test drives, more than 200 hours of driving and more than 8,000 km driven with electric and conventionally driven vehicles did not show an overall significant difference in driving dynamics between electric and conventionally driven vehicles, although the vehicles – in particular their engine power - would have facilitated such differences.

We found larger differences between different concepts of power transmission than between the two engine types. According to our results, e-cars are built in a way that they mimic the feeling of a car with automatic gear shift, e.g. if the driver releases the brake without pressing the accelerator pedal, the car starts moving. We concluded that the majority of drivers determine driving speed by haptic impressions, i.e. they stay within individual comfort zones hardly influenced by the car's capabilities and constraints. This applies to longitudinal as well as to lateral acceleration. Different from what was expected, the maximum acceleration was higher for the two c-cars than for the e-cars. There was a careful comparison carried out for certain particular situations like roundabouts, curves and acceleration after a vehicle standstill. In general, no significant differences in speed and acceleration/braking behaviour were found between e-cars and c-cars. Direct implications to road safety by deploying use of e-cars cannot be expected from this perspective.

One significant difference between e-cars and c-cars could be detected: Releasing the accelerator pedal implies different behaviour for the e-cars. Deceleration is used to regain at least a small proportion of the energy used for acceleration, i.e. recharge the batteries by recuperation. There are e-cars, which offer the opportunity to adjust the level of recuperation, e.g. the Mitsubishi i-MiEV. As clearly visible in the data, the level of deceleration achieved by recuperation is considerably higher than the engine brake of the c-cars in the experiment. According to the results of the questionnaire survey, drivers quickly get familiar with that, but other surrounding and follow-up vehicles' drivers might be surprised. Moreover, the level of deceleration by recuperation is very close to the threshold of deceleration, which requires the brake lights to be activated at $-1\ m/s^2$ according to ECE R13 (United Nations Economic Commission for Europe, 2010). It may be assumed that high levels of deceleration without the brake lights surprise many road users and hence, they are a potential danger to road safety. Therefore, an appropriate level of deceleration for recuperation or a lower threshold for brake lights should be subject to further research.

5. Conclusions

This paper explored the differences in vehicle dynamics and drivers' behaviour between personal e-cars and conventional personal cars with a combustion engine. Our research aimed at revealing potential safety risks due to a higher e-car penetration, e.g. incidents or conflicts with other road users that primarily occur with e-cars involved. To this end, we conducted a real-world driving study with 90 subjects and collected more than 200 hours of driving data. Regarding driving dynamics, we found larger differences between different concepts of power transmission than between the two engine types. None of the extraordinary driving events identified could be qualified as typical phenomenon related to the nature of the engine. Thus, our analyses of driving dynamics do not reveal direct safety risks due to electric engines. However, compared to the engine braking of conventional cars, surprisingly high decelerations were measured during the e-car's recuperation phases, which might lead to risks for follow-up drivers, since the brake lights did not activate in most cases. We recommend that manufacturers of electric cars should consider this issue in future. Questionnaire results showed that the subjects felt a clear difference between electric and combustion engine cars, but more related to the lower perceptibility of e-cars due to less noise emission. This is certainly a research topic, which is already being handled in various international projects.

Acknowledgements

This work was performed in the scope of the research project E-FFEKT, which was funded by the Austrian Federal Ministry for Transport, Innovation and Technology. We would like to thank all members of the project consortium and give gratitude to all persons responsible for the programme "sicher-elektro-mobil" of the Verkehrssicherheitsfonds.

References

Carroll, S. (2010). *The Smart Move Trial - Description and initial results* (p. 32). UK: Cenex, UK. Retrieved from http://www.cenex.co.uk/LinkClick.aspx?fileticket=yUKAcRDJtWg%3D&tabid=60

Carroll, S. (2011). *The Smart Move Case Studies* (p. 49). UK: Cenex, UK. Retrieved from http://www.cenex.co.uk/LinkClick.aspx?fileticket=1PElynEh5mA%3D&tabid=474

Garay-Vega, L., Hastings, A., Pollard, J. K., Zuschlag, M., & Stearns, M. D. (2010). *Quieter Cars and the Safety of Blind Pedestrians: Phase I* (DOT HS 811 304). Cambridge, MA: U.S. Department of Transportation - Research and Special Programs Administration - John A. Volpe National Transportation Systems Center.

Jabeen, F., Olaru, D., Smith, B., Braunl, T., & Speidel, S. (2012). Acceptability of Electric Vehicles: Findings from a Driver Survey. In *Shaping the future: linking research, policy and outcomes: Australasian Transport Research Forum 2012*. Perth, WA, Australia.

Lenz, G., & Aytan, A. (2012). *COEXIST - Anforderungen von Elektromobilität an Stadt- und Verkehrsplanung zur Wahrung der Verkehrssicherheit* (1. Zwischenbericht).

Morgan, P. A., Morris, L., Muirhead, M., Walter, L. K., & Martin, J. (2011). *Assessing the perceived safety risk from quiet electric and hybrid vehicles to vision-impaired pedestrians* (Published Project Report PPR525).

Pollard, J. K., Guthy, C., Hastings, A., Stearns, M. D., Garay-Vega, L., & U.S. Department of Transportation. (2012). Evaluation of Sounds for Hybrid and Electric Vehicles Operating at Low Speed. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *56*(1), 2206–2210. doi:10.1177/1071181312561465

Sandberg, U., Goubert, L., & Mioduszewski, P. (2010). Are vehicles driven in electric mode so quiet that they need acoustic warning signals? In *Proceedings of 20th International Congress on Acoustics, ICA 2010*. Sydney, Australia.

Santini, D. J. (2011). Electric Vehicle Waves of History: Lessons Learned about Market Deployment of Electric Vehicles. In *Electric Vehicles The Benefits and Barriers* (p. 240). InTech.

Singh, S. (2010). 360 Degree Perspective of the Global Electric Vehicle Market - Opportunities and New Business Models. Frost & Sullivan.

United Nations Economic Commission for Europe. (2010). *Regulation R13: Uniform provisions concerning the approval of the vehicle classes M (except M1), N and O with regard to braking*.

Wall Emerson, R., Naghshineh, K., Hapeman, J., & Wiener, W. (2011). A pilot study of pedestrians with visual impairments detecting traffic gaps and surges containing hybrid vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*(2), 117–127. doi:10.1016/j.trf.2010.11.007