DEVELOPMENT AND EVALUATION OF A DRIVER COACHING FUNCTION FOR ELECTRIC VEHICLES

Monika Jagiellowicz, Michael Hanig, Marcus Schmitz

Wuerzburg Institute for Traffic Sciences (WIVW)

Robert-Bosch-Straße 4, 97209 Veitshoechheim, Germany

schmitz@wivw.de

ABSTRACT:

Several different driver coaching approaches exist that aim at supporting eco-friendly driving. Most of these approaches have been designed for vehicles with combustion engines and could therefore not be simply adapted to fully electric vehicles (FEV) as of the different vehicle architecture. The paper at hand outlines a driver coaching function that has been developed especially for FEVs. It aims at improving an efficient driving style and thus should support the driver optimising energy consumption and remaining range. The coaching function provides specific visual real-time feedback via a head-up display addressing several different aspects of the driver behaviour. A driver coaching study has then been conducted to evaluate the coaching concept and to compare it with two further common coaching approaches. The study results show a significant improvement of energy efficiency as well as the usefulness and high acceptance of the specific driver coaching function. On the basis of these results, the paper also discusses the possibility of implementing an active forced-feedback pedal as a reasonable feedback channel for driver coaching.

1 INTRODUCTION

Considering the relatively low range of electric vehicles compared to vehicles with combustion engine and the associated range anxiety (see e.g. [1]), eco-driving is becoming an important approach by which means range may be extended. Several different driver coaching approaches exist that aim at supporting eco-friendly driving [2-4]. These coaching approaches differ mainly regarding feedback time (real-time vs. post trip) and regarding their functionality (general feedback vs. context specific feedback). However, most of these approaches have been designed for vehicles with combustion engines and could therefore not be simply adapted to fully electric vehicles (FEV) as of the different vehicle architecture (e.g. regenerative braking).

The paper at hand outlines a driver coaching function that has been developed especially for FEVs and aims at improving an efficient driving style and thus extending remaining range. The coaching function provides specific real-time feedback as previous research has shown that immediate feedback has significant impact on the driving style when linked to the particular situation [4, 5]. The coaching function addresses six aspects: hard acceleration, exceeding speed limits, speed behaviour while cornering, deceleration towards lower speed limits, speed behaviour at hilltops and downhill sections, and car following.

In order to evaluate the driver coaching concept, a driving simulator study has been conducted, in which the coaching concept has been compared with two further common coaching approaches: (1) a verbal instruction prior to the drive which explains how to drive efficiently with electric vehicles, and (2) an unspecific feedback in real-time during the whole drive.

2 METHOD

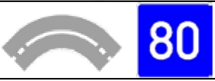
2.1 Research question

By means of the driver coaching study the following research questions are about to be investigated: a) which impact has specific real-time coaching on energy consumption, b) how much do drivers benefit from specific coaching compared to unspecific coaching or to sole verbal instruction, c) how far does the specific real-time coaching change the driving behavior, and d) how acceptable is specific driver coaching?

2.2 Driver coaching variants

The first of the three coaching variants (VER) makes use of verbal instructions prior to the drive (see Table 1, left). In the second variant (COA) the driver also gets the verbal instructions. In addition, he receives situation specific real-time advices via the head-up display (see Table 1, right). These advices correspond with the verbal instructions. In the third variant (SKA), the verbal instructions are also given prior to the drive. In addition, the driver obtains via the head-up display a consumption scale with a pointer indicating whether he drives more or less efficient than a reference driver.

Table 1: Verbal instruction and corresponding real-time coaching advices.

Verbal instruction	Specific advice
Omit hard accelerating	
Do not exceed the current legal speed limit	
Keep constant speed while negotiating a curve	
Decelerate by means of the electric brake Try to omit hydraulic braking by means of anticipatory driving	REKUP!
Sail over hilltops / sail when driving downhill in order to gain speed	SAIL!
Keep a sufficient distance to leading vehicles in order to omit velocity fluctuations.	

2.3 Study design

The study was conceptualized as a 3x2 experimental design with randomized distribution of participants to one of three experimental conditions (i.e. VER, COA, SKA). The first factor is a between-subject factor with three levels comprising the three types of coaching. The second factor is a within-subject factor with two levels comprising the repetition of the test run (baseline vs. experimental run).

2.4 Description of the simulation environment

For the coaching study, a static driving simulator with an electric vehicle and consumption model was used. The driver's view is realized by means of three flat screens (42" diagonal each) enableing a view of 180°. The head-up display was integrated into the bottom part of the mid plasma screen indicating the vehicle's speed and a) the coaching advices or b) the consumption scale. The vehicle was equipped with a combined pedal solution (one-way pedal solution), which has implemented the electric brake on the accelerator pedal (i.e. releasing the accelerator pedal leads at some point to the onset of the electric brake) [cp. 6]. The maximum electric brake force realizes -1.7 m/s².

2.5 Test track

The test track was designed in a way that allows experiencing all driving situations which may be critical regarding energy efficiency and are addressed by means of the driver coaching (i.e. inclines, declines, sharp curves, car following situations, several changes of speed limit, intersections with stop signs, and intersections with traffic lights). It has a total length of 15 kilometres and could be driven through in about 15 minutes.

2.6 Test procedure

Each testing trial took approx. 90 minutes. Participants were explained that the study is investigating specific functionalites of electric vehicles. In a short driving trial the participant could get familiar with the electric vehicle model, the static simulator, and the combined pedal solution.

In the following, all drivers performed the baseline drive with the instruction to apply their natural driving style. At this point, participants are not aware that the upcoming test runs are about efficient driving. According to the experimental group, the drivers obtained either the verbal instruction only or additional specific or unspecific real-time advices. After the experimental drive participants obtained a questionnaire on acceptance and workload.

2.7 Participants

All participants (N=30) were trained and experienced drivers from the test driver panel of the WIVW. The sample included 16 women and 14 men. Mean age was M=33 (sd=14) years.

3 RESULTS

3.1 Energy consumption

First of all, no significant difference in energy consumption could be found in the baseline drive comparing the three experimental groups ($F(2,29)=0.013$; $p=.987$).

Secondly, the average energy consumption could be significantly reduced from 1.77 kWh in the baseline to 1.30 kWh in the COA condition, $t(9) = 4.76$, $p < .001$. Drivers in the SKA condition benefited comparably from the unspecific coaching, t(9) = 7.17, p < .001. Drivers in the VER condition saved 22 % by means of the verbal instruction, t(9) = 9.31, p < .001.

Thirdly, there is no significant effect on the consumption between the experimental conditions, F(2, 29) = 1.83, p = .180. The mean consumption in the conditions COA and SKA tends to be lower than in the VER condition (see Figure 1).

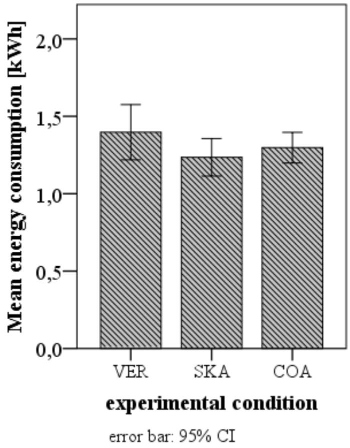


Figure 1: Mean consumption for the three experimental coaching conditions in the second drive.

3.2 Driving behaviour

Concerning the driving behavior, there is a significant effect of the experimental condition on the two parameters a) velocity, F(2, 29) = 3.94, p = .032, and b) positive acceleration, F(2, 29) = 5.85, p = .008. As can be seen in Figure 2 (left) mean velocity is lowest for the COA condition and highest for the VER condition (COA vs. SKA: t(27) =-1.00, p=.330; COA vs. VER: t(27) =-2.77, p=.010; SKA vs. VER t(27) =-1.78, p=.087). Mean positive acceleration is significantly higher in VER compared to COA and SKA (COA vs. SKA: t(27) = 0.43, p=.674; COA vs. VER: t(27) = 3.15; p=.004; SKA vs. VER: t(27) = 2.73, p= .011) (see Figure 2 right).

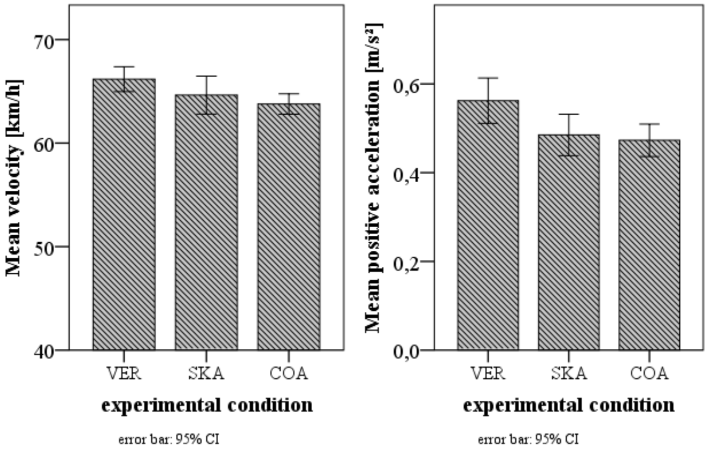


Figure 2: Mean velocity (left) and mean positive acceleration (right) for each experimental condition.

No differences could be found with regard to deceleration by means of electric braking, $F(2, 29) = 2.86$, $p = .075$, although this parameter tends to be lowest with COA (see Figure 3 left). This tendency fits with the results on sailing, where also no significant total effect of the experimental condition could be found, $F(2, 29) = 2.46$, $p = .105$, but in COA least time tends to be spent with sailing as can be seen in Figure 3 (right).

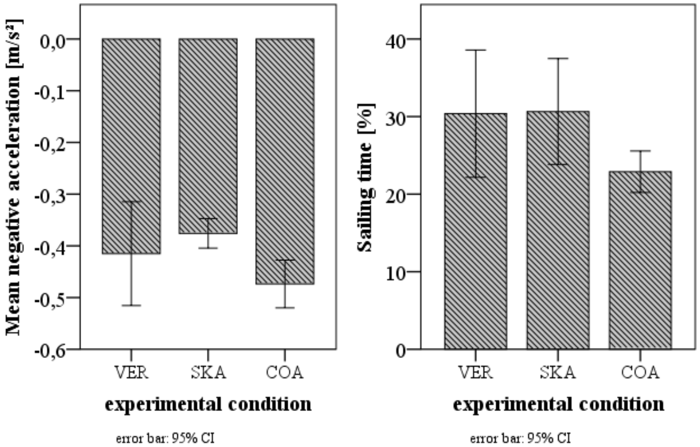


Figure 3: Mean negative acceleration (left) and mean percentage of sailing time (right) for each experimental condition.

For parameters as usage of the hydraulic or electric brake (as a percentage of total time) no differences were found between the three groups for the experimental drive.

3.3 Acceptance of specific real-time advices

Drivers assessed the specific coaching to be helpful in order to improve efficient driving and the advices were rated to be not frustrating, disturbing or distracting, but quite motivating and understandable. Most criticism was expressed concerning the very restrictive velocity advice and the accuracy of the recuperation advice as participants sometimes reached the according velocity too early or too late.

4 DISCUSSION

The study results show a significant improvement of energy efficiency by means of the driver coaching function. All three approaches could significantly decrease the energy consumption compared to the baseline drive, with significantly lower savings for the verbal instruction. Specific and unspecific feedback could gain comparable savings.

The coaching advises (in addition to the verbal instruction) had a high impact on driving behaviour (especially compared the verbal instruction only). This results in lower average velocity, lower acceleration, higher deceleration by means of electric braking, and less sailing time. Further, the specific driver coaching shows a high usefulness and acceptance. However, the recuperation advices have to be optimized and the advice “exceeding speed limit” has to be individually adjustable in order to further increase acceptance.

As a summary, the specific real-time coaching is recommended due to the guidance towards specific efficient driving behaviour patterns and due to the possibility of advice-free driving, which reduces distraction. Continuing studies should investigate whether it is possible to further reduce distraction and workload by means of the implementation of an active accelerator pedal into the driver coaching function. In doing so, some icons may be removed from the visual channel or some advices could be applied even more precisely, as for example the recuperation advice. The added benefit of an active accelerator pedal should be investigated in further studies.

Acknowledgment: The study was conducted in the frame of the eFuture project [7] that was partially funded by the European Commission under FP7.

References:

[1] Franke, T., Neumann, I., Bühler, F., Cocron, P., & Krems, J.F.: 'Experiencing range in an electric vehicle - understanding psychological barriers'. Applied Psychology: An International Review, 2012, 61(3), 368-391.

[2] Felstead, T., McDonald, M., Thorpe, N. & Fairchild, R.: 'D4.2D Field trials, plans, results and outcomes.' Foot-LITE project, 2011 (01.10.03.08/52C).

[3] Boriboonsomsin, K., Vu, A. & Barth, M.: 'Co Eco-driving: Pilot Evaluation of driving behavior changes among U.S. Drivers', Report UCTC-Fr-2010-20, 2010. University of California Transportation Center.

[4] Van der Voort, M., Dougherty, M.S. & van Maarseveen, M.: 'A prototype fuel-efficiency support tool'. Transportation Research Part C, 2001, 9, 279-296.

[5] Kuiken, M. J.: 'Instructional support to drivers. The role of in-vehicle feedback in improving driving performance of qualified motorists'. PhD thesis, University of Groningen, 1996.

[6] Schmitz, M., Jagiellowicz, M., Maag, C. & Hanig, M.: 'Impact of a combined accelerator–brake pedal solution on efficient driving.' IET Intelligent Transport Systems – Special Issue: Human-Centred Design for Intelligent Transport Systems, 2013, 7(2), 203-209.

[7] http://www.efuture-eu.org, accessed February 2014