User perspective on eco-driving HMIs for electric buses in local transport

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Abstract

Eco-driving plays a crucial role in the optimal use of electric buses in local public transport. Human-machine interfaces (HMIs) can support eco-driving but have to meet specific user requirements. We developed an indicator-based eco-driving interface prototype and then conducted an interview study with electric bus drivers (N = 10) to examine their perspectives regarding key features of eco-driving interfaces. Based on drivers' statements, interfaces should specifically highlight whether the driving behavior is currently lying within an acceptable range of energy efficiency rather than highlight exceptional driving behavior. Furthermore, this feedback should always be based on an adequate amount of reference data from routes that allow for comparability. The overall information volume of eco-driving interfaces should be reduced and these should rather provide feedback about few selected core eco-indicators.

1 Introduction

Electrification of local public bus transport is a key measure to reduce transport emissions (Perrotta et al., 2014). Yet, it is crucial to support energy-efficient driving (i.e., eco-driving; Barkenbus, 2010) to ensure optimal utilization of battery resources. Potential energy consumption savings of electric buses in local transport due to eco-driving have not been investigated in large-scale field settings yet. Nevertheless, by means of field experiments (Zhou et al., 2016) or simulation studies (Perrotta et al., 2013) first studies indicate a possible improvement in energy efficiency of about 15%. Electric vehicles (EVs) have specific energy dynamics such as the bidirectional energy flow due to regenerative braking that constitute challenges and opportunities for eco-driving and related interface design (Strömberg et al., 2011). While previous research on EV eco-driving interfaces mostly focused on individual car use (e.g. Dahlinger et al., 2018), the context of electric trucks and buses has received limited attention so far. Particularly for complex settings such as electric buses used for public transport in cities where

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vehicle handling, driver goals, and cognitive load are different to private cars, a good understanding of the user perspective and users' action regulation (Frese, 2009) is important to effectively support eco-driving (Tozzi et al., 2016; Arend & Franke, 2017). Therefore, the objective of the present research was to examine the drivers' perspective regarding key features of eco-driving interfaces for electric buses. To this end, we developed a first prototype comprising essential elements of an action-integrated eco-driving support system and then conducted a qualitative interview study with electric bus drivers to examine the user perspective.

2 Prototype Design

The prototype of the eco-driving support system "Eco-Assistant" was developed within the framework of the NuR.E project focusing on user-centered range management for electric buses. Based on single-case interviews at an early stage of the project, drivers have only very limited time and cognitive resources to pay attention to an eco-driving interface while driving a bus in city traffic. So, for the first prototype, we decided for an indicator-based feedback design to provide drivers with specific goal-directed feedback regarding key aspects of their driving behavior (i.e., action-integrated feedback): besides (1) a general indicator of *overall efficiency* (energy consumption in kWh/km), action-specific indicators related to (2) *acceleration* (kWh consumed per accelerated km/h), (3) *regenerative braking* (share of km during braking without using friction brake) and (4) *momentum exploitation* (share of km with no additional energy input; i.e. letting the bus coast). The selection of the final indicators was based on existing literature on eco-driving strategies and interface designs e.g., for (hybrid) electric vehicles (Arend & Franke, 2017; Neumann et al., 2015) or conventional trucks (Fors et al., 2015) and iteratively adapted to electric buses. These four indicators are visualized as icons that change appearance based on the drivers' eco-driving performance. More specifically, an average score of indicator data over the last 5 kilometers is calculated (current score) and compared to the average score of the 5 kilometers before (reference score). If the current score is better than the reference score, the indicator icon turns green. If it is worse or equal, it turns gray. If the current value is the worst value of the entire day it turns red and if it is the best value of the day it turns green with a golden frame. This simple feedback logic was chosen to alert drivers of variations in energy efficiency without defining an absolute performance criterion. Figure 1 shows the visual prototype.

3 Method

A qualitative interview study with 10 bus drivers (2 female) with first experience in driving an electric bus (average driving hours: M = 14.6, SD = 8.8, Min = 4, Max = 30) was conducted. After the first part of the interview (not part of this analysis), participants were shown a video introducing the "Eco-Assistant"-prototype. The interviewer asked then four prototype-related interview questions: "To what extent would this interface support you in energy-efficient driving?", "To what extend do you rate the information to be presented well comprehensible? What is unclear? Where do you see room for improvement?", "Which of the information displayed do you consider to be especially helpful regarding energy-efficient driving? Which information could you leave out?", "Is there any further information missing that you would consider as helpful regarding energy-efficient driving?" Audio recordings were transcribed verbatim and in-vivo coding was conducted to extract the interface features electric bus drivers perceived as supportive for eco-driving and features that were not deemed as supportive. All mentioned features were listed and clustered as feature groups.

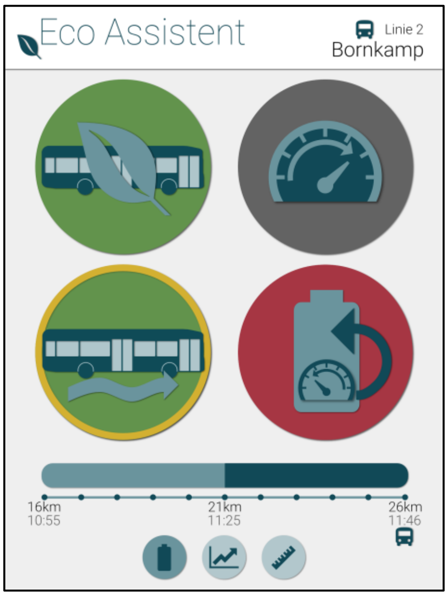

Figure 1: The "Eco-Assistant", an eco-driving HMI prototype for electric buses. Indicators are overall efficiency (top left), acceleration (top right), momentum exploitation (bottom left), regenerative braking (bottom right). The bar below the indicators shows the reference period of the indicator scores.

4 Results

In the interview, drivers discussed in particular features of following feature groups (number of participants with at least one code in this feature group in parentheses): the driving-specific data or content the indicators should convey (8), the amount of indicators or information that should be displayed simultaneously (4) and what has to be taken into account when calculating specific indicators (3), the way feedback is provided regarding these indicators (9), what references scores or comparisons should underlie the provided feedback (3), the personal value they expect from an interface (4) and how an interface should be installed (2) and used (3) in the electric bus. Here, we focus on user responses regarding the kind and number of indicators as well as the logic of the provided feedback.

Several participants stated that all indicators are relevant (4). Nevertheless, the *momentum exploitation* indicator was highlighted (4) compared to the other indicators *("Well, I like the* *momentum exploitation […] like for example when approaching a bus stop, there's no point in accelerating again to arrive less than a second earlier but lose a kilometer of range.")*. The *regenerative braking* indicator was highlighted least often (1), moreover, three participants even suggested to drop this indicator. Concerning information volume, participants stated that one indicator would be enough (1), that two is the optimal number of indicators (1) and that the HMI requires too much effort if used in everyday bus driving (2), which results in four participants suggesting less information volume (*"Because I won't pay attention to it. I drive according to my feeling; or rather I also have to pay attention to the traffic and the passengers and cannot constantly look at it.")*. Feedback indicating that the eco-driving behavior is within an acceptable target range (6) was mentioned more often than other types of feedback like rewarding exceptionally good eco-driving behavior (3) or warnings at problematic driving behavior (1) (*"Well, I like the coloring […], because you can identify it faster than looking at some sort of an index pointer. When I have green, I know: 'Ok, everything done right', when red: 'Ok, you should do something', when gray: 'Ok, I am in a normal range'."*). Participants stated that the reference route for the feedback calculation should be long enough (2) and allow for comparability of reference routes (e.g. by using the same bus line route; 2).

5 Conclusion and Next Steps

The present study made a first step in examining requirements of electric bus eco-driving HMIs by discussing key features of an indicator-based eco-driving HMI prototype with electric bus drivers. First, the suggested eco-indicators were generally perceived as relevant by drivers yet further research is needed to validate how well different indicators can actually quantify differences in energy efficiency in the context of electric buses driving in city traffic. Second, user responses highlight that reducing information volume is a key requirement for the examined usage context. This poses a significant challenge for action-integrated interface design that targets to provide more precise (i.e., action-oriented) information than only overall energy efficiency. Third, instead of a reward/punishment-type feedback for exceptional driving behavior, users tend to prefer feedback indicating that their driving behavior lies within a certain 'green range' where no further behavior adjustment is necessary. Fourth, the feedback should always be based on an adequate amount of reference data to increase comparability of driving conditions. However, the design implications of this study are limited by the low electric bus driving experience of the participants and that the prototype was only video-presented and not tried out in a real bus. All in all, further research is needed to examine the dynamics of different possible metrics to quantify energy efficient driving behaviors in electric bus operation. Examining users' responses after gaining extended experience with such eco-driving indicators is another key step for the further advancement of eco-driving HMIs.

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References

Arend, M. G., & Franke, T. (2017). The Role of Interaction Patterns with Hybrid Electric Vehicle Eco-Features for Drivers' Eco-Driving Performance. *Human factors*, *59*(2), 314-327.

Barkenbus, J. N. (2010). Eco-driving: An overlooked climate change initiative. *Energy Policy, 38*(2), 762-769.

Dahlinger, A., Wortmann, F., Ryder, B., & Gahr, B. (2018). The Impact of Abstract vs. Concrete Feedback Design on Behavior Insights from a Large Eco-Driving Field Experiment. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (p. 379). ACM.

Fors, C., Kircher, K., & Ahlström, C. (2015). Interface design of eco-driving support systems - Truck drivers' preferences and behavioural compliance. *Transportation Research Part C: Emerging Technologies, 58,* 706–720.

Frese, M. (2009). Towards a psychology of entrepreneurship—an action theory perspective. *Foundations and Trends® in Entrepreneurship*, *5*(6), 437-496.

Karlin, B., Zinger, J. F., & Ford, R. (2015). The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin*, *141*(6), 1205.

Neumann, I., Franke, T., Cocron, P., Bühler, F., & Krems, J. F. (2015). Eco-driving strategies in battery electric vehicle use–how do drivers adapt over time?. *IET Intelligent Transport Systems, 9*(7), 746-753.

Perrotta, D., Macedo, J. L., Rossetti, R. J., Afonso, J. L., Kokkinogenis, Z., & Ribeiro, B. (2013). Driver attitude and its influence on the energy waste of electric buses. In *Simulation of Urban Mobility User Conference* (pp. 99-108). Springer, Berlin, Heidelberg.

Strömberg, H., Andersson, P., Almgren, S., Ericsson, J., Karlsson, M., & Nåbo, A. (2011). Driver interfaces for electric vehicles. In *Proceedings of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 177-184). ACM.

Sullman, M. J., Dorn, L., & Niemi, P. (2015). Eco-driving training of professional bus drivers–Does it work?. *Transportation Research Part C: Emerging Technologies, 58,* 749-759.

Tozzi, M., Bousse, Y., Karlsson, M., & Guida, U. (2016). A European initiative for more efficient and attractive bus systems: the EBSF_2 Project. *Transportation Research Procedia*, *14*, 2640-2648.

Zhou, B., Wu, Y., Zhou, B., Wang, R., Ke, W., Zhang, S., & Hao, J. (2016). Real-world performance of battery electric buses and their life-cycle benefits with respect to energy consumption and carbon dioxide emissions. *Energy, 96,* 603–613.