Emergent properties of interaction and its implications for the design of electric vehicles

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ABSTRACT
Presented is a qualitative study that captures the experience of 16 first-time drivers of electric vehicles (EVs) taking part in a field study. The semi-structured interviews exposed the attributed functionality of the elements of the interface and their role in driving EVs. In particular, the importance of estimated range is highlighted. Findings show how drivers handle (learn) the range of the vehicle by exploring estimated range in terms of (a) the output (e.g., remaining range: 5 km) and (b) the dynamism of the same value (e.g., the slow/fast change) as well as (c) its combination with other information sources. The drivers' active search for immediate feedback, in addition to the accumulated/archival feedback, is highlighted. Presented is the current use of design elements and its implications for design.

Categories and Subject Descriptors
H.5 [**Information interface and presentation**]

Keywords
User experience, Human machine interaction, electric vehicle, information processing, automotive interface, decision making

1. INTRODUCTION
The ELectrical Vehicle Intelligent InfraStructure project (ELVIIS) is a cross industry project with the goal to ease the charging process of EVs by means of intelligent technology, see https://www.viktoria.se/projects/elviis. Two field-studies, in which drivers experienced EVs for one month each, investigated the value of driving EVs (Study 1) and the potential added value of information technology in EVs (Study 2). Reported is the first field study (Study 1), focusing on the driving experience and the usage of elements of the interface as information sources to the decision making process "driving EVs to destination X". The field study focused on 3 aspects of the driving experience, (a) the value of EVs (i.e., benefits/scarifies), (b) range anxiety, and (c) Human-machine-interaction, of which the latter (c) is of interest in this work-in-progress paper.

2. METHOD
2.1 Data collection
Collected are the self-reported experiences of EV drivers using Volvo C30 electric as their main vehicle of the household, for one month. In total, 16 in-depth interviews were performed after the completion of an EV trail period; 7 women and 9 men. The age ranged between 29 to 61 years old. Nine of the drivers had no experience of EV while 7 of them had limited experience (i.e., driven an EV less than 5 times). The follow-up session consisted of semi-structured interviews divided in two parts. Part 1: the drivers' perceptions and attitudes towards the EV. This included open-ended questions regarding value creation and critical incidents. Part 2: the drivers' interaction with the EV. This included open-ended questions regarding the usability and functionality of the interface using probes in the format of reaction cards. Each interview lasted for about 60 minutes. Part 2 is of interest in this extended abstract.

2.2 Analysis
All interviews were transcribed and qualitative assessed using the principles of grounded theory, i.e. "open coding" was performed [1,]. All interview material was analysed in relation to the conceptual model of value of Lapierre [2] to identify the value of EVs. Furthermore, all material was analysed from the perspective of distributed cognition [cf., 3] to identify the emergent properties of the interaction between the driver and the interface; thereby being able to differentiate the functionality, information provided and role of the interaction. The activity of interest was constrained by the decision: "I will/will not drive to destination A" and how that activity changed during the physical activity of driving the vehicle. Three levels of themes were identified in the process of grounded theory, "open-coding" [6] (cf. Section 3).

3. RESULTS AND ANALYSIS
Among the 16 drivers taking part in the study, *estimated range* was ranked as the most important information source (cf. Table 1). Other important sources were the *power meter* (N=4), *speedometer* (N=4), *battery status* (N=3), and *energy consumption* (N=1). Interestingly, each of the information sources had different function for each of the drivers (cf. Table 1). For instance, *estimated range* did not only provide information regarding the range of the vehicle (i.e., amount left) but also the success of charging, the effect of driving style, etc. Exploring the change (dynamism) of the value (i.e., the difference/fast/slow/sudden changes) allowed the drivers to use it as immediate feedback on, e.g., their driving style, increasing their understanding of how to drive EVs. This can be compared to the less used power meter (i.e., the intended immediate feedback provider). Moreover, using on the output of the value allowed the driver to use it as a warning (i.e., reference point), highlighting current progress. Interestingly, the battery status (0-5 filled boxes next to each other) intended to show progress was used to indicate current status.

Further analysis shows that a great majority of the drivers [D2, D4, D6, D8-D16] used two or more information sources in combination. This, in turn, expanded the functionality and added value of the sources (cf. Figure 1). In particular the following themes emerged: (a) increase the reliability/credibility; (b) lower uncertainty/ insecurity; or (c) to learn about the EV in terms of cause-effect relationships. Interestingly, as can be seen in figure 1, estimated range has most connections to other information sources

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(N=4), followed by the battery charge status (N=3). It was most common to compare estimated range with the battery status (N=4). Also, the analysis suggests that the confirmation and ability to compare builds confidence of the drivers.

Table 1. Qualitative assessment of transcripts from the perspective of distributed cognition [9]

Source (N=number)	Level 1 analysis- condensed citation (D=driver)	Level 2 analysis – emergent functionality
	Information provided	*Role of activity*
Estimated range (N=16)	Information on current reach [D1-D11, D13-D14]	Feedback
	Information on the need for charging [D7, D16]	Feedback
	Information on driving style [D3, D11-D12, D16]	Feedback
	Information for competition with myself /others [D3, D9]	Reference point
	Information to be used for planning [D5, D13,D15]	Warning/ reference point
	Knowledge on the overall "health" of the EV [D10]	Warning
	I can see the saving potential [D3]	Reference point
	I know the current charging status [D9]	Warning
	Information on previous usage [D10]	Feedback
Power meter (N=4)	Information on current driving style [D7, D9, D13],	Feedback
	Information to understand the behaviour of the EV [D7],	Feedback
	to be used as a reference point [D11].	Reference point
Speedometer (N=4)	Information on speed [D2, D11, D14, D16]	Feedback reference point
Battery status (N=3)	Information on charge status [D1, D6, D15]	Feedback
Energy consumption (N=1)	Information current driving style [D12]	Feedback

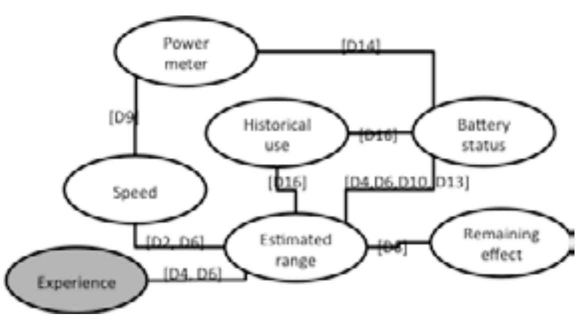

Figure 1. Physical (e.g., power meter) and non-physical information sources (e.g. experience) were combined to (a) add value, (b) increase understanding (c), or learn the effect of ones actions.

In addition, the results (level 3 analysis) indicate that the context of the activity (short/long trips, known/unknown destinations, first week/last week) was different between the different identified attributed functionality (cf. table 1). However, further investigations are needed.

4. DISCUSSION AND CONCLUSION

EVs provide a new set of information technologies and there is not yet a standard way of designing them [4]. This study highlights current use of interface elements and thereby gives suggestions for the design of such interfaces. For instance, it is noted that drivers compare and contrast the information provided to them to e.g. understand the effect of range and energy consumption (cf. 5-6), this feature may be utilised to a greater extent in the design of the interface by, e.g., providing proximity of typically combined information sources. Furthermore, the importance and multiple utilisation of "range estimation in km" highlight the drivers' current "locus of attention". Indeed, some of the participants did not notice warnings far away from the estimated range value. The focus towards this information source may be due to the ease of use, familiarity (similar information are present in gasoline vehicles), memorability of a specific value as compared to a scale, the continuous (visually) notable change in value, or the importance of the value due to the limited range of EVs. The findings indicate that the drivers consciously monitor this area (which should be explored by designers), and there are room for enhancing the design of the value in line with the attributed functionality (cf. Section 3), e.g., the use of colour to indicate progress to "empty".

5. ACKNOWLEDGMENTS

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