Driver Interfaces for Electric Vehicles

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ABSTRACT

The dissemination of electric vehicles (EVs) is an important step towards a more sustainable transport system, but barriers to adoption persist. Much effort and resources are put into solving battery technology related issues and progress is made continuously. There remain however important matters that have not been equally discussed; the design of user interfaces and human-machine interaction (HMI) of EVs is one.

This paper seeks to examine a few of the issues regarding EV HMI through a study that evaluates two different concepts for an EV instrument cluster in order to develop knowledge on (i) what information is relevant to present to the driver of an EV and (ii) how that information should be presented; innovatively or in a more familiar way. Two consecutive user tests, according to a between-subject procedure, were used to test two concepts in a driving simulator. Ten participants, with little or no experience of driving an electric or a hybrid electric vehicle, tested each concept. The participants were asked to drive the EV simulator and to interact with the user interface while different events were triggered, designed so that the participants would experience several of the situations that might appear when driving an EV for a longer period of time. Data was gathered through objective measurements, e.g. time, number if errors etc., as well as through questionnaires and interviews.

The results show that participants had problems understanding the EV specific information content independent of concepts, even though they considered the information shown to be the right one. Both concepts had advantages and disadvantages, most notably that participants expected the vehicle to work like a conventional car when the interface was traditional and that they felt insecure when the interface was innovative.

Some of the discovered problems can be attributed to the participants’ lack of knowledge and useful mental concepts regarding electricity and batteries, which made understanding the information difficult. More research on how to support EV drivers through design of the HMI given these deficiencies is needed.

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Categories and Subject Descriptors

H.5.2. [User Interfaces]: ergonomics, screen design, user-centred design

General Terms

Design, Human Factors.

Keywords

Electric vehicles, Human-Machine Interaction, Instrument Cluster

1. INTRODUCTION

1.1 Background

The dissemination of electric vehicles is fundamental to the creation of a future sustainable transport system. As more and more electric vehicles (EVs) enter the consumer market in the form of Battery Electric Vehicles (BEVs, or Full Electric Vehicles, (FEVs)) and plug-in hybrids (PHEVs), this is coming closer and closer to reality.

The demand for EVs has shown to be strong, especially in metropolitan areas [8], and continuous effort is put into the development of battery technology; the root cause of many previously identified barriers to adoption. These barriers include high initial acquisition cost, lack of supporting infrastructure and slow recharging [9]. Improvements in rapid recharging and storage capacity are acute issues for EV developers in order to increase range and decrease battery size [2, 13], but improvements in energy density are to be expected [2].

One aspect of EVs that has not been the centre of as much effort and discussion is Human-Machine Interaction (HMI). However, in order to fully maximize consumer adoption of EVs the design of the HMI is an important aspect. Hence, HMI and driver information in EVs have been identified as the new frontier for automobile designers [1]. Reports from larger field studies have come to the conclusion that the current designs of EV HMI have deficiencies, and can lead to confusion and ignorance among drivers [7, 11].

1.2 HMI related issues in electric vehicles

EVs present the driver with a range of new and unfamiliar technologies and it will be vital for automotive manufacturers to
make the driver’s interaction experience positive and rewarding
[16]. Drivers of electric vehicle will encounter completely new
concepts such as charging procedures and recharging duration
while using an electric vehicle in comparison to a conventional
car. The all-electric car driver will also be faced with other
characteristics that differ from conventional cars including limited
driving range per full charge cycle, very low noise, strong
acceleration and limited space [4] in addition to unfamiliar issues
such as novel start and stopping procedures and the effect that
driving style has on the potential mileage range [16].

Because they are driven on electricity, electric vehicles will
naturally need to display different information about energy than
conventional vehicles such as the amount of electricity stored and
expected mileage on current charge [7, 15]. This information is
critical to drivers [15].

Another new aspect of electric drive is regenerative braking,
where energy is recovered when the vehicle is braking, coasting
or going downhill. This requires some changes in driving style,
how much is decided by the technical configuration of the system
[15]. Studies have found that this takes some time getting used to
[5, 16], but that drivers respond positively and try to maximize the
energy they can recapture and hereby extend their range [15].

Current battery technology only allows for a limited range in
comparison to conventional vehicles. Depending on the size and
design of the vehicle the range is between 60-200 km [14]. Even
if this range has shown to be sufficient for most trips [12] 80%
with Mini-E, [13] 95% with a range of 100 miles) and drivers’
daily use [10, 15] limited opportunities to recharge en-route [13]
require more planning of journeys and charging [16], and drivers
become more conscious about their journeys [9]. The limited
range of the vehicles places extra emphasis on displaying useful
range related information and guidance to drive energy-efficiently
[7].

A considerable concern for inexperienced drivers is running out of
charge in the middle of a trip as a consequence of the limited
range [5]. This anxiety is reduced with experience, as drivers get
used to the normal range of their car and learn that it is sufficient
[9], but worries remain for more experienced drivers about unplanned trips, e.g. to the hospital. Some more experienced
drivers display concerns about the range as they feel they cannot
trust the information regarding the range and battery status
provided in the car. The information on range fluctuates because
of factors not known or understood by drivers, the range decreases
more rapidly than seems reasonable to drivers, and the information is therefore deemed unreliable [16].

The effect of in-vehicle systems is one factor to be aware of. Since in-vehicle systems, such as air conditioning, defrosters and
entertainment system, are also run on energy from the battery the range can be affected by turning these systems on or off.

Because of the silence of EVs, especially at low speeds [6], the
driver does not receive the same auditory feedback from the
battery and electric engine as in a conventional car [16]. Even if
drivers find the silence enjoyable while driving [6], it leads to
some issues. Knowing whether the vehicle is ready to drive is one
of these. Conventional cars provide a number of sensory cues
such as engine cranking noise and a small vibration in the vehicle
when turned on. An EV does not which means that the driver
needs to be informed when the powertrain is ready [3].

To summarize, the vehicle needs to convey energy related
information in a reliable and precise manner to drivers that are
inexperienced with electric energy measurements as well as
different ways in which to display that information. The driver
should understand how to utilize the EV’s special driving qualities
and should be aided in developing an understanding of what
factors affect the available range to reduce concerns, including
being guided to energy-efficiency and encouraged to use
regenerative braking. There is however as yet not enough
knowledge regarding how to design an EV HMI in order to
overcome these issues. More research is needed on what specific
information to include in the interface as well as on how to
present it.

This paper explores the problems surrounding EV driver
interfaces and the user issues connected to them, trying to find a
way forward for an HMI more adapted to the needs and
expectations of drivers of EVs.

2. AIM AND QUESTIONS POSED
The aim of the study described in this paper was to evaluate two
different ways of presenting instrumentation information to the
driver of an EV. The ambition has been that the result from the
study should bring us closer to answering the following questions:

- What is the relevant information content that needs to be
  presented to the driver of an electric vehicle?
- How, i.e. in what form, should these relevant parameters
  be presented?
- Can perception of information relevance be influenced? Can
  the information content be perceived as more or less
  useful depending on the way it is presented?
- Should the interface be traditional, i.e. similar to that of a
  conventional internal combustion engine vehicle, or not? Can
  the shift in technology be used to create a new, innovative kind of vehicle interface?

This study has focused solely on the instrument cluster, and the
information it contains. The center console, infotainment and
navigational information, as well as external devices have not
been considered. Neither is the necessary interaction when
charging the vehicle included in the study.

3. METHODOLOGY
Two consecutive studies of two different concepts for an EV HMI
have been conducted in order to investigate the aforementioned
issues.

The studies were carried out as user tests in a driving simulator
according to a between-subject procedure. The simulator used was
the driving simulator facility at Saab Automobile AB in Trollhättan, Sweden. This consists of a full-sized Saab 9-3 sedan
vehicle body placed in front of a three by twelve meters
cylindrical screen giving the driver a 220-degrees view around
the car. The car is fully functioning, but does not move, which
means that the driver will not experience forces of acceleration etc. The
instrument panel cluster has been replaced with a digital display
allowing full freedom of different virtual concepts to be tested.

3.1 Participants
Ten persons, of which 50% were male and 50% female, tested
each concept. Their ages ranged from 27-61 years (mean = 44
years) with an even distribution. The participants had no, or very
little, experience of driving an electric, or a hybrid electric
vehicle, but all were very familiar with a Saab 9-3.

3.2 Data collection
The tests were documented by two test leaders who recorded the
entire test by taking notes of actions and statements made by the participant. When seated in the simulator the participants’ interactions with the vehicle were logged, e.g. to measure time, which buttons were pressed and how many times, in order to give an indication of how well the interface functioned. In addition, subjective data was gathered by means of questionnaires and interviews. Throughout the interaction with the EVs HMI in the simulator the participants were also asked to “think aloud”, so that their immediate reactions and chain of thought could be recorded.

3.3 Procedure
Each test was run according to the same procedure and divided into four parts; pre-test questionnaire, test of interface while stationary, test of interface while driving and post-test questionnaire and interview. In the pre-test questionnaire information on the participants’ background was collected along with information regarding their experience and attitudes towards electric vehicles and vehicle interfaces in general. The second part took place with the participant seated in the driver’s seat of the simulator where they were asked to try and identify the different gauges and information pieces visible on the instrument cluster. They were also asked to perform five tasks with the car computer. After this, they were asked to start the car and drive for a while whilst thinking aloud and reflecting on their perception of the interface. During driving, they were exposed to three events; State Of Charge-level on red, a “charge car now”-message and telltale, and the “limited performance”-message and telltale. In order to be able to fit these tasks in a logical order within the limited timeframe of the test, the original State Of Charge level was set to 35% and the events were speeded up. The participants were informed that events would happen quicker than if it would have been a real vehicle and trip. They were also given the task to accelerate and brake hard a couple of times to experience the function of the ecometer. Throughout the stay in the simulator one test leader sat in the front passenger seat of the car, asking questions and recording the actions of the participant while the other test leader sat in an adjacent control room controlling the interface when called for and recording what the participant said.

Finally, after the driving session a questionnaire was administered to collect information on the participants’ views of the design of the HMI, and a complementary interview was conducted to elicit additional information about their opinions and understanding of the interface.

Each test took approximately 60 minutes and about a third of that time was spent driving.

4. THE CONCEPTS
Two instrument cluster concepts for an EV were created. The basic functions of the EV were a battery and an electric motor giving a range of about 200 km on full charge, and regenerative braking. The top speed was limited to 160 km/h.

4.1 Concept 1
The layout of Concept 1 was based on the current layout of the Saab 9-3 instrument cluster and retains the placement of gauges and display but with different content. It has a traditional look for cars and should feel very familiar to drivers of Saab cars. All primary information is shown in analogue form, with dials and needles.

The concept is shown in Figure 1. To the left is a dial showing Distance To Empty (DTE). It also includes the propulsion ready-symbol (green vehicle with double-sided arrow) that is lit when the car is ready to drive. In the middle of the instrument cluster is the speedometer and below it the car computer showing current gear, outside temperature, and odometer data. This is also where information will appear when something happens. To the right is a combined dial including a gauge for Auxiliary Load (denoted A) showing all energy used not directly going to the engine, an Ecometer displaying instantaneous energy-efficiency, and a gauge for State Of Charge (SOC) (denoted by a white battery symbol). The Ecometer needle is vertical when the car is standing still, and moves to the left when decelerating and to the right when accelerating. The green field on the left side is used to inform the driver that the vehicle is regenerating power. The SOC-scale ranges from full (1/1) to empty (no marking) and the yellow battery symbol visible beneath the SOC-scale is lit when 15% remain. When DTE reaches 15 km the message “Battery level low. Charge now!” appears with a plug-telltale (see Figure 2).

When the vehicle has problems delivering full function, “Limited performance” is shown on the display along with a turtle-telltale (see Figure 3).

4.2 Concept 2
Concept 2 was designed based on the results of the user test of

![Figure 2. “Charge now!” telltale](image)

![Figure 3. “Limited performance” telltale](image)
Concept 1 and with the aim of responding to the issues discovered. It attempts to educate the novice electric vehicle drivers on the different aspects of EV, by allowing the driver to go deeper into different aspects. It also gives the drivers the possibility to customize the instrument cluster so that they can themselves decide what information is important for the moment. The more innovative look of the interface aims to “remind” drivers that this is a new type of vehicle, not just a conventional combustion engine vehicle.

The graphic style of Concept 2 is inspired by the interfaces of other battery-operated products rather than traditional vehicle interfaces (see Figure 4). The speedometer to the left still has the traditional look, but has been cropped on one side to leave more space for the other information. The speedometer houses the ready-symbol, in this concept a green car with the text “READY” underneath. To the right of the speedometer is a screen divided into six subsections. At the bottom is the current time, (space for) turning indicators, outside temperature, odometer data and what is currently playing on the entertainment system. When something happens a pop-up will appear in the middle of the screen and then retreat to the left side of the car computer in the form of a telltale.

The other five subsections are expandable boxes containing the remaining information. In Figure 4 the DTE box is expanded showing the available range and the distance to a target, both in numerical form and as a graph. When the box is minimized a column showing the DTE in bar graph form will be visible. The SOC information is shown in the form of a battery (common e.g. in mobile phones) and when expanded will include battery temperature and health. The menu box expands to reveal the menu system. The Ecometer shows instantaneous energy-efficiency where the meter is fully green when the driver is maximally efficient and expands to include a historic overview of how efficient the driving has been. The rightmost subsection is Electricity Consumption and shows how much energy is currently used by additional systems in the vehicle such as air conditioning and sound system. The subsection expands to show which systems are on and how much energy each of them are using, and how much range is lost because of it.

5. RESULTS
5.1 Concept 1
The overall impression of Concept 1 was, according to the participants, that it felt like the instrument cluster of a conventional car, which made them feel familiar and secure. It was found to be clear, distinct, and easy to read. The layout with the analogue dials and the speedometer in the middle was very appreciated.

5.1.1 Distance To Empty
The DTE gauge was initially confused with a tachometer by half of the participants since it was placed in the slot normally occupied by the tachometer and was not visually distinctive. When the participants had noticed it was a DTE, it was judged as important and clear. This was the piece of information that the largest proportion of participants judged as most relevant.

![Image of instrument cluster in Concept 2 with DTE expanded and expanded boxes of SOC, Ecometer, and Electric Consumption in that order.](image-url)

Figure 4. Above is the instrument cluster in Concept 2 with the DTE expanded and below are the expanded boxes of SOC, Ecometer, and Electric Consumption in that order.
5.1.2 State Of Charge
Specific questions about the SOC gauge were not included in the first test, but it was generally perceived as the fuel gauge on a conventional car: good to have and easy to read.

5.1.3 Auxiliary Load
Understanding the Auxiliary load gauge was a big problem for the participants; over half of them disagreed completely with the statement “The meaning of the auxiliary load gauge was clear”. It had an imprecise name that did not communicate its intent and there was no unit that could give any further clue to its function. The design of the scale was counter-intuitive to the participants, who could not comprehend why the size of the green bars got smaller when the needle went up. (It was supposed to indicate being less “green”, or economic, when auxiliary load was high and therefore the size of the green bars field decreased towards the top.) A further issue was that the participants could not judge what effect that the energy used had on the range. Neither did it provide guidance to what action(s) to take, i.e. which systems to turn off. The label “A” led the participants to believe that it was connected to the unit Ampere, which was something they could relate to electricity and figured might be of importance in an EV. Even so, Auxiliary load was still judged as a rather important piece of information.

5.1.4 Ecometer
The Ecometer was perceived as quite irrelevant compared to the other gauges (even though with a large deviation in the judgement of “relevance”). The participants did not fully understand the behaviour of the gauge, some exhibited confusion about that the needle went in different directions from the middle and some that it went to red when braking, since they felt it should be regenerating no matter how hard you pushed down the brake pedal. One participant requested a meter showing instantaneous consumption in “numbers”. Those who understood the meter found it fun to try and keep the needle in the middle, driving as economically as possible.

5.1.5 Tell-tales and Warnings
The warnings were considered visible for too short a time according to the majority of the test participants. They understood the “Charge Now” warning and tell-tale but had problems with “Limited Performance”. The turtle symbol was associated with something moving slowly, but the participants did not relate it to the reduced power of the vehicle. Even when the participants read the text they had trouble reconciling the turtle with the car, and what it could mean in the context of EV.

The propulsion ready symbol was not noticed by most of the participants and it was difficult to understand for those who saw it, since the participants did not associate the symbol with driving. The symbol for battery low was also difficult to see; during the simulation only half of the test participants noticed the symbol while driving.

5.2 Concept 2
Concept 2 was generally not as well received. The digital look, with very distinct representations of bars and green boxes, was perceived at the same time as cluttered and with lots of space. The graphics were too big, but difficult to read, and many of the participants would have preferred a more analogue look. It caused one participant to exclaim “D.T.E, S.O.C, E.C.O. all of these letter combinations!” suggesting that the participants perceived the novelties as slightly overwhelming.

The use of configurable boxes was positively received, mainly because of the ability to customise. At the same time the participants found it hard to imagine when they would need the extra information, and could not find a suitable box to expand during normal driving. Expanding a box meant that this information became too dominant, and all other information would be overshadowed. Some participants felt that all information but speed and state of charge was unnecessary unless you were low on battery.

The fact that the speedometer is not positioned in the middle of the cluster was considered a huge drawback for the layout. It was considered the most important piece of information and should be centred so that the risk of distraction is reduced.

5.2.1 Distance To Empty
The DTE meter was considered very useful and easy to understand. The participants wished, though, that the distance to charging stations and other relevant places could be shown along the bar instead of “home”.

5.2.2 State Of Charge
All of the participants understood and appreciated the SOC gauge, but some felt that the battery temperature information included in the expanded view was hard to relate to. One participant said “Temperature? I don’t know what temperature a battery should have, but the health says good so it looks good”. However, the health of the battery was considered something that would become more important the older the car got.

5.2.3 Electric Consumption (Auxiliary Load)
When just looking at the slim version of Electric Consumption none of the participant understood what it was supposed to represent. The expanded version managed to explain the meaning of the meter and it was easily understood, but not considered very useful even though it pointed to which systems were the major “energy thieves”. According to the participants it would be interesting to learn that the auxiliary systems affected the energy consumption but only once.

The participants could not relate to the unit Watt, and therefore did not fully understand what to do with the information. Only one participant noticed the “estimated range loss” text and thought that it was far more interesting than the much Watt-numbers. The participants were slightly divided as to whether the electric consumption was important or not, but leaning towards the relevant side.

5.2.4 Ecometer
Half of the participants did not understand the Ecometer when looking at it for the first time. Also after driving some issues remained. Some participants thought that it denoted instantaneous consumption and were surprised when the green dots disappeared when accelerating. Others thought it was slow and lagged, because they did not recognise that the vehicle recovered energy when braking. A few asked if you should not be able to see regenerative braking somewhere in the interface. The expanded view did not mean anything to the participants, as it was so unspecific about what the bars indicated.

5.2.5 Tell-tales and Warnings
The warning pop-ups were received positively. It was considered good that they popped up as large boxes so that you noticed that something happened, and that they then retreated to the corner where they could be read afterwards, if you had been too busy in a difficult traffic situation to read them when they first appeared.

The propulsion ready symbol was difficult to notice despite being
quite big; only half of the participants noticed it. The green car with the text “READY” underneath made the symbol easy to understand once seen.

6. DISCUSSION

6.1 Information content

One question that exposes important issues for an EV instrument cluster design is what information content needs to be presented to the driver of an EV. The major part of the participants in both tests thought that the concepts contained the information you would need when driving an EV and could not imagine any additional information that they would like to have or need.

According to [3] one of the unique requirements for EVs is that the instrument cluster should contain a some kind of “meter” showing the power drawn from the battery to provide an idea of instantaneous energy use and how economic the driving is. In many EVs this information is represented in the form of a powermeter that has two important functions. One is showing how much energy is being used in kW or percent, and the other is indicating that energy is being recovered through e.g. regenerative braking. It is usually placed in a very prominent position on the instrument cluster [16]. In the two concepts tested in the study this corresponds to the Ecometer with the difference that the Ecometer does not provide a clear measurement of the power and does not explicitly state that the battery is regenerating energy, especially not in Concept 2.

The Ecometer was the piece of information considered the least relevant in both concepts, which might be connected with its vagueness and the difficulties of understanding the movement of the meter. However, [15] found that the powermeter investigated in their study, the Mini-E, was too detailed for most drivers. Only a few of the drivers reported being able to use it to drive more economically, while a larger group would have preferred a simple indicator of whether the vehicle was using or recovering energy. This indicates that the relevant function of the meter is to see if the vehicle is regenerating or not. Neither of the Ecometers tested in this study managed to successfully convey the concept of regenerative braking and how the vehicle should be driven to maximize its effect. The lack of understanding for the concept of regenerative braking may therefore have contributed to that the Ecometer was not considered that significant.

The participants’ grasp of regenerative braking could, however, have been different if the force feedback in the pedals would have been more realistic. The Mini-E users indicated, for instance, that the feeling in the pedal was very important for the encouragement of using regenerative braking and that trying to maximize the effects of energy recovery through only using the accelerator pedal was fun [15]. The regenerative braking is constructed differently in the tested EV and both brake and accelerator can be used to achieve regeneration.

Several of the participants in the two tests questioned the need for both DTE and SOC gauges, most considered though the DTE to be the most important one. When questioned about their reasons most of the participants concluded that having both was probably a good solution after all, as it could be hard to translate one into the other when the information was needed. Since the relationship between SOC and DTE is not as intuitive as that between fuel level and driving range in conventional cars, other studies have shown that both are actually useful as they allow drivers the opportunity to see how the amount of required energy is related to the driving conditions and driving style [3, 16]. As it has been noted that EV drivers sometimes have difficulties understanding why DTE readings fluctuate [16], information that help them comprehend the relationship between SOC, DTE, driving conditions and behavior are important in creating a mental model of the inner workings of an EV and can lead to that EVs are utilized in a more efficient way.

The Auxiliary load gauge is quite an unusual instrument and is not included in surveys of EV instrumentation [3, 16]. It was however considered relevant by the participants in the two tests, especially when low on charge. As long as the battery level was high the information was interesting, but not important. What the participants really wanted to know was what effect the energy used by the auxiliary systems had on the available range, the estimated range loss included in Concept 2, and what systems they should shut off if they wanted to conserve energy. Including auxiliary load in the instrumentation cluster made the participants contemplate the fact that energy is not only used to propel the vehicle, there are additional systems in the car that also use energy, something that very few had considered before. This is an important realization towards using an EV in an efficient manner and extending its range.

The study shows that improved information is needed to indicate to the driver whether the vehicle is ready to drive or not. The participants in both tests had problems recognizing this. The symbols indicating that the propulsion system is ready did not appear to be effective, probably due to a combination of the drivers’ expectations of what is going to happen not being met and the drivers’ lack of experience to know what to look for. The propulsion ready symbol was too difficult to notice as the participants were too used to auditory feedback (engine running) at this point, a problem noticed also in other studies [16]. This issue is not made easier by that the fact that you start the car by turning an ignition key, which is an act intimately connected with turning on a conventional car, and thus carries all the expectations that come with it [16].

6.2 Presentation format

The second key question to discuss in regards to EV HMI is how the information should be presented. Two different directions of HMI design can be taken; either the interface design can be traditional and familiar to the driver or it can be innovative and fresh. The advantages and disadvantages of both can be noted in the results from the two tests.

According to the results of the tests the layout of Concept 1 was more popular than Concept 2. It was greatly appreciated that Concept 1 looked like the instrument cluster of a conventional car. According to the recommendations of Biscarrat [3] the instrument cluster of an EV should be designed to appear familiar, as it will be easier for the driver to adapt to the vehicle and consequently feel comfortable and secure when driving the vehicle. The participants in the test of Concept 1 certainly felt secure and comfortable, but the familiarity with a conventional car did not facilitate their adaption to the EV. Instead it caused them to assume that the instruments were the same as in the conventional car and, further, that the vehicle functioned in the same way. As a consequence they had trouble understanding the aspects specific to the electric car and the behaviour of the instruments.

The different look of Concept 2 made the participants aware that this was a new type of vehicle and they more easily accepted that it functioned differently. However, the new look also made them feel more insecure and more hesitant towards the vehicle and the interface. They were more reluctant to guess what the instruments
The problem then still remains that drivers do not comprehend supported by findings in field studies where drivers have driven preferences and judgements of relevance.

Since the design of the two instrument cluster concepts differed in their representation of the information, more than just the chosen presentation principle, this may have affected the participants’ preferences and judgements of relevance. Regarding the higher level of appreciation for Concept 1 compared to Concept 2 this can largely be attributed to the familiarity of the layout, as earlier mentioned, and the fact that the speedometer was centred. Both these aspects are in turn influenced by the fact that the participants in the tests all were Saab employees with a very strong connection to the Saab design identity and that particular layout of an instrument cluster.

The specific representation of the information pieces, i.e. the design of the gauges and meters, may also have had an effect on how relevant the information seemed and how easy it was to understand for the participants. The Ecometer can be discussed in light of this. Information on driving efficiency is usually portrayed using metaphors or abstractions, like growing leaves, in order to get drivers relate their actions to a larger goal [16]. In the two concepts tested this information was represented either by a colour shift between green and amber or as a score of green dots, with the green colour being the only thing that connected the meter to the overall goal in terms of better for the environment. This may have affected the perceived relevance negatively. However, in the interviews made with the participants it was clear that they had connected the Ecometer to an efficiency goal and that the relatively low relevance score could be explained by some participants’ negative attitudes towards driving energy-efficient per se. It is difficult to say based on the collected material whether a more metaphorical representation of the ecometer would have increased the participants’ understanding of it.

The participants in the tests preferred the instrument cluster to have a more analogue look, even if those participants testing Concept 2 had no problems quickly getting an overview of the meters in bar graph form. This could be a result of that they felt more confident with analogue dials.

6.3 Underlying issues
As the test of Concept 1 resulted in that the participants did not fully understand what it meant to drive an electric vehicle, Concept 2 was created with the intent of being more educational. The solution was not altogether successful. The participants considered the educational efforts unnecessary after a first look and further that the information was interfering while driving. They did not seem to develop a better understanding of what it meant to drive an EV. These results correspond to those generated in other studies [11], which show that efforts made to educate drivers through power flow and consumption charts are more likely to confuse drivers than to help them and that the drivers loose interest in trying to understand after a period of time.

The problem then still remains that drivers do not comprehend what it means to drive a car powered by electricity, a conclusion supported by findings in field studies where drivers have driven their car for up to a year. One example is Cocron et al. [7] who concluded that drivers are unsure of what it means to have a car driven by electricity and that they need be supported accordingly.

An important part of the problem seems to be to get an insight into the concept of electricity itself. The participants in the study seemed to have little knowledge of electricity and how information about it could be presented in a vehicle setting. They tried to remember what they knew from before and apply this knowledge, which meant that they recognized W as denoting Watts and A as denoting Ampere, but were unsure of what to do with the information after that. One participant stated that “Ordinary people cannot relate to Watt”, a statement which the test results support. The matter of electricity knowledge is reinforced by findings in other studies; drivers are inexperienced with electric energy measurement and ways of displaying that information [15]. The tests of the concepts also revealed that the participants had problems relating to information about the battery, except for its state of charge. They did not know what characteristics the battery should exhibit. Findings in other studies show that drivers in general have an inappropriate mental model of how batteries work and they remain unfamiliar and uncomfortable with the technology even after longer exposure [11].

The lack of understanding of the interfaces show that more consideration needs to be taken to understanding the drivers of EVs and how they will come to perceive the aspects that differentiate an electric vehicle from cars they are used to driving.

7. CONCLUSION AND FURTHER STUDIES
The results from the study stress the question marks surrounding which information content is relevant to the driver of an electric vehicle. Even though the participants felt satisfied with the information presented in the two concepts, the result of the tests reveal that they did not comprehend important aspects of EVs, which indicates that there was information missing. This impression is strengthened by comparisons to other studies. It can be concluded that the information content in EV’s instrumentation clusters needs to be further refined.

Neither of the presentation formats tested was entirely successful, as the traditional interface hindered the participants’ adaption to the EV by making them believe everything functioned as in a conventional car while the innovative interface was perceived as harder to read and made them feel insecure and uncomfortable.

The study shows that there are underlying issues to the participants’ problems with understanding the EV HMI. Drivers lack knowledge on electricity and do not have useful mental models of e.g. batteries, issues that are critical to understanding why the vehicle will behave the way it does. This points to that further research is needed in order to find ways to communicate the concept of electricity and how a battery powers a car to drivers.

The study was carried out in a simulator and the participants’ comments are based on a short test. In order to develop further knowledge on the driver’s requirements for an EVs HMI, the interface will, among other issues such as adoption and use patterns, be evaluated further in a large-scale field test planned to be executed during autumn 2011 and a year forward.

8. ACKNOWLEDGEMENTS
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9. REFERENCES


