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WHAT DOES IT TAKE TO MAKE ELECTRIC CAR CHARGING 'SMART'?

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Research paper

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Abstract

In this paper, we argue that the electrification of cars is not simply a move from fossil fuel to electric energy. It also integrates the car into the household energy system in ways that challenge assumptions that car charging is made 'smart' primarily through AI-powered app-based digital services that help the user to make energy-, and cost-efficient decisions in terms of when to charge the car. As we will demonstrate in this paper, our design ethnographic study of how nine households learn to charge their cars according to their family routines and values shows how smart charging is not merely due to specific technological features. Instead, charging habits evolve through anticipatory experiences of what smart technologies come to mean to family members through their use. Based on our research, we recommend a smart charging service design that affords multi-operation ability, co-learning ability and social accessibility.

Keywords: Smart charging, Smart technologies, User experience, Design ethnography, Electric vehicles.

1 Introduction

What does it take to make an electric vehicle (EV) charging 'smart'? This paper elaborates on this question as it has been identified as key for making the massive contemporary transport electrification sustainable in its implementation through digital charging services (Shepero et al., 2018; Spencer et al., 2021). The European Commission's new car and van CO_2 target legislation 2021/0197(COD) suggests that only zero-emission vehicles can be sold from 2035 in the EU and stop the sale of vehicles with Internal Combustion Engine (ICE). If this legislation is accepted, we can expect new challenges for local electricity distribution grids, especially with expected clustering effects around vehicle charging stations, depots and households. Also, the recent surge of energy prices in Europe since Russia's invasion of Ukraine has significantly increased the energy costs for private households (Ari et al., 2022) and increased the differences up to 100 times between the high and low hourly set electric energy price at the Nord Pool energy market (www.nordpoolgroup.com). Thus, the charging of EVs needs to be 'smart', i.e., managed to be evenly spread out, so that not all EV charging takes place during existing electricity system peak times (often from 4 to 9 PM) when often people arrive home from work.

This leads to two assumptions about why digital 'smart' charging services are needed from both a macro and micro perspective. First, from a societal perspective, energy usage must be spread out during the 24 hours to avoid stress on the energy grid and lack of energy production. Second, from an individual

perspective, EV users want to charge when the momentary energy price is low to avoid high running costs. What we refer to as ´smart´ charging in this paper is the collaboration between human and intelligent technologies and services to charge EVs in a better (´smarter´) way both according to the end-user's needs as well for the society of sustainable energy generation and distribution.

There are different ways how to do ´smart´ charging, which is managed through technologies that either shift the time of day of charging to better fit with grid conditions (available power in the local grid), momentary energy price or enable EVs to charge from the grid or discharge energy stored in their batteries to the grid, to reduce stress and cost of energy (Spencer et al., 2021). To study the effectiveness of these technological advances, studies are being done by modelling and simulating EV driver behaviour to find out the major influencing factors of the charge and discharge load of electric vehicles (Wen et al., 2020). Studies in real-world situations are done by analysing actual driver data to test and analyse driver responses to optimisation signals (Bauman et al., 2016), and the effectiveness of various signals in yielding desired charging schedules together with driver incentives on altering driver behaviour (Spencer et al., 2021). Analysing large data sets has proved to be useful in terms of understanding how large numbers of users change their behaviour in response to already pre-defined EV charge management strategies.

"Smart" is often used as a term to describe an intelligent machine or algorithm by the industry, however, what people identify as smart or intelligent might differ from the technical definition and is not fixed in their everyday life, but rather actively seen and enacted in the world (Taylor, 2009). People are not always taking decisions based on rational aspects as they might not purely act from their individual perspective on technology in their social context of everyday life. To better understand what 'smart' charging means in everyday life and what implications that means for design, we will do this by addressing the following research questions:

How does EV charging become 'smart' in people's everyday life? And what are the implications of this when designing for home-based EV charging?

To address these RQs, the paper investigates how families in households create their own EV charging strategies over time based on family interests, routines and values. This is based on a study where we have shifted perspectives toward understanding the experience and mechanisms between household members and smart charging technologies. We argue that we can develop new and innovative design and management strategies for home-based EV charging services if it's based on an understanding of how members in households experience and cope with smart charging technologies in their everyday life.

2 Complicating Smart Charging

We see our work as a contribution to the emerging field of people-centric HCI research on the social life of smart EV charging services that are set to identify and enable routines for sustainable home energy consumption. In this section, we will discuss two lines of arguments that float through contemporary academic, industry and policy discourse on smart charging, and discuss how recent research from people-centric perspectives urge us to re-frame these arguments through deeper understandings of how the 'smartness' of new technologies becomes negotiated when it becomes entangled in the complexities of social life (Geeng & Roesner, 2019; Luria et al., 2020). Homes are complex social spaces with multiple people of different roles, genders and ages (Cohen et al., 2016; Geeng & Roesner, 2019). This provides unique challenges for designers of smart home technologies (Alam et al., 2012; Brush et al., 2011; Zeng & Roesner, 2019).

Firstly, we will address the assumption that the implementation of algorithm-driven charging services in private households will provide EV owners with an uncomplicated way to let the smart charging technology 'take over' the control of when to charge and reduce charging costs for them. As we have seen in our research, this 'hand-over' might instead be understood as a redistribution of initiatives that opens up new possibilities for people to develop their own charging strategies.

Secondly, this leads to the other argument, that algorithm-driven charging services will per definition optimise time and cost efficiency, without paying attention to how the meaning of 'smartness' is re-negotiated when appropriated by people through social interactions within households and communities. In the following sections, we will elaborate on these arguments and how they have been critically examined in recent research.

2.1 Who is in charge of charging?

As we described in the introduction, the effects of smart EV charging from an energy grid perspective seem promising based on quantitative smart charging studies (Refa & Hubbers, 2019; Spencer et al., 2021). The increase in EV use in privately owned households in recent years has gone hand in hand with the growing societal trend of becoming more self-supplying with electric energy or reducing energy costs through solar panels and smart energy management (Bourgeois et al., 2015; Svangren et al., 2018). However, aligning charging and energy generation to a lower cost and reducing CO_2-footprint has been proven to induce tensions within households around motivations, roles, mobility patterns or selection of technology for energy management (Svangren et al., 2018). In this context, smart charging services have been developed with the ambition to make EV charging easier, more environmentally friendly, more cost-effective and to reduce the stress on the household fuses and local grid. These technologies are set to help end-users delay the charging to hours when the energy price is lower and there is less stress on the electric energy systems (Delmonte et al., 2020). Scheduled charging can be divided into two categories, such as; a) User Managed Charging (UMC), where the end-user manage the scheduling themselves and thereby determines the timing of charging based on information about e.g. of energy hourly spot price, or b) Supplier Managed Charging (SMC) where the supplier manages the timing of the charging to the lowest spot price and the user only set the preferred time when the charging shall be finished (Delmonte et al., 2020).

In this project, we have focused on the SMC category of smart charging services, although the participants could override the smart charging functionality. Delmonte et al. 2020 found out that users preferred UMC instead of SMC, as UMC was perceived as providing more control and less risk of finding their cars not fully charged when needed. In turn, SMC was identified as better from a societal perspective. The lack of control in SMC was also identified as an issue for end-users in a practice-based design research about an Artificial Intelligent (AI) controlled charge point for EVs (Alfrink et al., 2022). This research showed that more information to increase the transparency about the AI algorithm did not necessarily ease understanding or provide relevance to the end-users. It was shown that the added transparency instead put additional cognitive demands on people by shifting the responsibility to the users, but without providing them with enough possibilities for control.

There has been recent research in developing a Human-Centred Artificial Intelligence (HCAI) framework for Reliable, Safe and Trustworthy (RST) intelligent systems (Shneiderman, 2020). Shneiderman proposes a framework that clarifies how to; design for high levels of human control and high levels of automation to increase human performance; understand the situation which needs full human control or high automation; and avoid the problems of too much human or computer control. This framework suggests that achieving high levels of human control and high levels of computer automation is possible. From this perspective, we understand smart EV charging services to be highly automated in terms of having computational power to calculate the optimal time for charging based on several inputs. At the same time, smart charging invites other forms of human control as people's everyday lives include a lot of decisions, priorities and routines that the technology will not be able to take into account.

Early studies of smart charging suggest that there are more drivers for EV users beyond the monetary incentives that should be taken into consideration when designing smart charging services or innovative business models in this domain (Will & Schuller, 2016). In the next section, we will discuss this in terms of how smart charging is experienced in its use.

2.2 Experiencing smart charging

When smart EV charging services became part of people's household energy systems, smart charging systems could be seen as an example of smart home technology. People's experiences of 'smart' home technologies and how to design these systems have been an increasing interest to the HCI community (Brush et al., 2011; Paay et al., 2022) and several papers have proposed design guidelines for smart home technologies (Alam et al., 2012; Geeng & Roesner, 2019; Mennicken & Huang, 2012; Röcker et al., 2005; Schiffhauer et al., 2016; Yang et al., 2017). Although the increasing amount of HCI research on user experiences of smart home technologies, specific research on how members within a household experience smart technologies for charging their cars, is so far quite limited (Henriksen et al., 2021). However, there is some interesting HCI research in recent years that has been made about everyday life with EVs (Bourgeois et al., 2015; Jensen et al., 2019; Lindgren et al., 2018; Svangren et al., 2017, 2018, 2022). These studies focus on electric car charging in the home and public context and found different challenges for EV owners to charge; e.g. of not being able to charge cars from their energy production because of intervening household practices (Bourgeois et al., 2015), underdeveloped installations of charging technologies (Svangren et al., 2018), becoming EV owners expectations that differ from the reality (Lindgren et al., 2018), or the lack of digital technology to fully support monitoring and planning of EV charging (Jensen et al., 2019; Svangren et al., 2018). Consequently, public EV charging is often facilitated by planning activities using applications that locate chargers to reduce range anxiety and worries about depleting the car's battery (Svangren et al., 2017) and relies on physical, digital and human infrastructure. In contrast to the problems of public charging, charging mostly at home becomes an appealing, preferred and convenient solution for many EV users living in private households (Hardman et al., 2018). However, connecting EV charging to household energy systems is not always easy. In the studies by Svangren et al. (2018) and Bourgeois et al. (2015), these studies identified challenges for people in households to align their energy production and charging of their cars with their energy production. Svangren et al. (2018) exposed how the problem for the household members didn't stem from a lack of awareness or interest in aligning the charging needs with production. Instead, the primary challenge was to accomplish this in everyday situations. Different routines, mobility patterns and attitudes within each household provided challenges in aligning household production and EV charging. These insights indicated dynamic and complex relationships between technology and household members. The study exposed how different members within a household had different willingness, attitudes and motivations towards alignment of energy usage and production. Most households in the study found technology helpful in charging their EVs through, e.g., UMC, however, the different needs of different members of the household made scheduled charging hard to manage. In their study they also found people improving or tinkering with the technology to fit personal needs and individual interests in the household.

In the global transition to electric mobility to reduce carbon emissions, smart charging technologies are anticipated to provide advantages for economic, environmental and social benefits. Several studies have reported on these benefits (Waldron et al., 2019), however few of them have yet been investigating the complexity of smart charging services about user behaviours and routines in a real-world context (Waldron et al., 2019). To bridge this gap also identified by others within the HCI field (Svangren et al., 2018), we chose an ethnographic approach to study people's experience of smart charging technologies in their everyday life settings, which will be explained in the next section.

3 Method

Our results presented in this article derive from an academic-industry collaborative research project about smart EV charging at private households, with the ambition to create synergies between academic ethnographic research and industry software design and engineering. This three-year research project was financed by a VINNOVA program (Swedish strategic innovation program), aimed at investigating sustainable future mobility solutions, and was a collaboration between a car manufacturer, energy providers, a research institute and academia.

Our approach included following nine households continuously and qualitatively through the life of the project. These households (see Table 1) were selected to give a variety of perspectives on car dependencies, with many planned and unplanned mobility needs in their everyday life. The households also met technical and geographical criteria set by the project intention to install a smart charging system prototype with real functionality in their homes and to be able to collect data from the participants' cars. Households with both Plug-in Hybrid Electric Vehicles (PHEVs) and 'pure' Battery Electric Vehicles (BEVs) participated in the study. Four of the households also produced their energy through solar panels. Through the project, the households were provided with a wall box for charging their cars (11kW AC, Type 2), a prototype of a cloud-based smart charging service and a smartphone app interface for the charging function. The smart charging function was optimising the cost of charging by controlling the time for charging depending on various sources such as momentary household peak load, hourly energy cost, vehicle usage, weather or user preferences.

Household (fictitious names)	Adults (Children)	Car usage	EV, solar panel and smart home experience
Andersson	2 (2)	One BEV and one ICE car. Both are used regularly by all in the household.	Have had BEV and PHEV experience before the project, but new to a BEV with a longer range to be used for longer vacation trips. Does not use a lot of smart home tech.
Bengtsson	2 (3)	One PHEV and one BEV. Both are used regularly by the parents.	Previous experience with a PHEV in the household, but new to a BEV. Have some smart home tech experience. Plan to get solar panels.
Fredriksson	2	One BEV. Used mostly by one in the household. The other uses public transport.	Long experience with PHEV and BEV. Have solar panels. One has knowledge and interest to monitor home energy use in detail.
Gunnarsson	2	One BEV. Used by both in the household, but mostly by one in the household.	Have had short and recent experience with a PHEV and am new to BEV. Does not use a lot of smart home tech.
Jonsson	2	One BEV and one ICE, both cars are used regularly.	Short previous experience with a PHEV and now very recently got a BEV. Not much experience with smart home technologies. Plan to get solar panels.
Karlsson	2 (2)	One PHEV and BEV. Both cars are used regularly.	New to both PHEV and BEV. Have recently invested in solar panels. Not much experience with smart home technologies.
Larsson	2 (2)	One BEV and one PHEV. Both cars are used regularly, however, they have mostly their "own" car for everyday use.	Are new to BEV during the project. Have not tried the BEV for longer distances. Had recently invested in Solar panels. Not much experience with smart home technologies.
Magnusson	2 (2)	One BEV and one PHEV. Both cars are regularly used by each parent.	Recent experience with PHEV and now new to BEV. Invested in Solar panels during the project. Not much experience with smart home technologies.
Nilsson	1 (2)	One BEV. Use the BEV both for long and short trips.	Have had some previous experience with BEVs. Have recent experience with solar panels and a huge interest in smart home tech.

Table 1. Overview of the participating households.

Our methodological approach combined ethnographic qualitative techniques with software design. This tailored *design ethnographic* approach (Pink et al., 2022), was deployed to form an iterative research and development process (see Figure 1), to engage both the stakeholders as well as the research participants in developing a smart charging system in line with already existing family practices, routines and values.

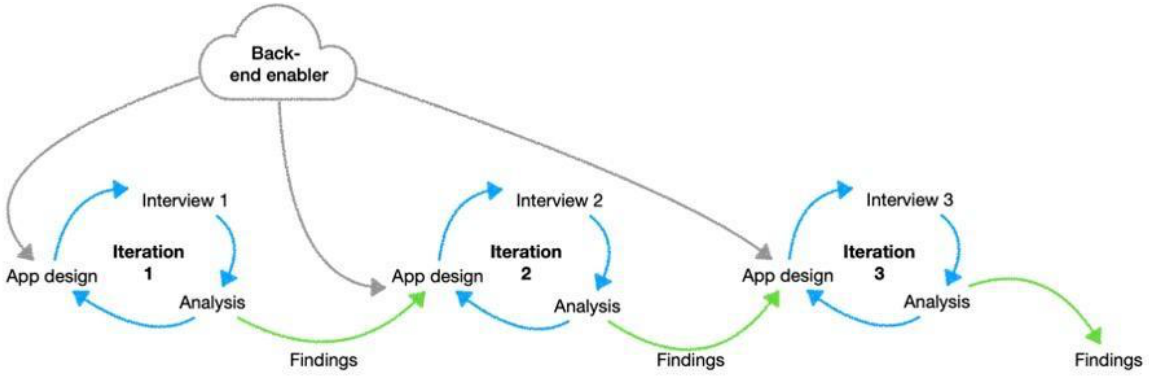

Figure 1 *Design ethnographic research and development process. This article focuses on the third set of ethnographic interviews in iteration 3.*

Semi-structured interviews and participant observations were conducted in each of the iterations staged to produce ethnographic knowledge about how the people in the households learned to live with the iteratively developed smart charging services provided through the project. This ethnographic knowledge was then used to provide insights to better understand what smart charging means for people in everyday life and what implications this has for the design of smart charging functions. In this article, we will primarily base our results on one particular ethnographic encounter one and a half years into the project (Iteration 3 in Figure 1). By this time in the project, we had already had several interactions with the research participants through ongoing conversations via phone calls and mail conversations around each household's electricity configuration, plans for energy optimisation, energy contracts, at-home parking routines etc. This was done to prepare the technical installation parts of the project, e.g., included the installation of a wall box in their homes that enabled the possibility to control the charging of their car(s). Before we describe in more detail the third iteration we will briefly present what we did in the first two iterations as background information:

In iteration 1, semi-structured ethnographic interviews were conducted at the project's onset, when most households were newly using PHEVs or BEVs and charging them slowly through 220V cables. Due to the Covid pandemic, these interviews were conducted remotely through video calls involving all family members, including children with driving licenses who also used the rechargeable car. The focus of these interviews was to understand participants' experiences and expectations of using EVs, including PHEVs and BEVs before being introduced to smart charging and any associated equipment. None of the participants had prior experience with smart charging. The installation preparation and process provided researchers with valuable insights into participants' charging routines, preferences, and expectations for the future, and participants in the households learned more about the technology being installed in their homes during this iterative process.

In iteration 2, after installing measurement equipment and wall boxes at each household, the second set of ethnographic interviews was conducted. At this point, charging was only controlled by a load balancing function and no user interface, such as a smartphone app, was yet available for participants to control or monitor the charging. The objective was to gauge participants' expectations of smart charging in terms of functionality, information, value, and potential impacts on their energy use and routines. Due to the Covid pandemic, the second set of semi-structured interviews was conducted via video calls with each family, involving other family members with driving licences to obtain a broader understanding of diverse or common understandings, values, and routines related to charging and energy usage.

In this paper, we will focus on the results from Iteration 3 and the third set of ethnographic interviews with participants in the nine households (table 1). At this stage of the project, the participants had been introduced to the smart charging algorithm and the first version of a basic smartphone app interface developed within the research project. In the smartphone app, see Figure 2 (left), they were able to monitor some basic data such as; their EV's battery charge level (in %); monthly total accumulated household used energy (in kWh) and generated solar energy produce (in kWh). They also had the

possibility in the app to manually set charging parameters to control the smart charging algorithm by setting the minimum EV battery charge level (in %) to be reached without any delay and the maximum charge level and the time (clock) when this charge level should be ready and finalised. The focus of this ethnographic encounter was not to evaluate different app user interfaces, but instead to use the app user interface as a probe in the interviews with the participants. This was used to spark conversations and learn about their evolving relations and anticipated use of smart charging services at home. Five of these households also had recently changed from a PHEV to a BEV during the time between the second and third interviews. As we had developed ethnographic knowledge about the households through the previous iterations, we could track contextual changes in their everyday lives, such as car use, work locations, Covid-19 pandemic impacts, energy spot price changes etc.

The ethnographic knowledge from this third encounter was produced through in-home interviews with two of the households for 2 hours and through 1.5-hour online interviews with each of the other seven households. The interviews were semi-structured and the overarching main question for the interviews was to understand what smart charging strategies they had developed so far and might develop in the future. The interviews were divided into two parts. First part aimed at understanding the changes since the last interview (6 months ago) regarding their car usage, energy cost awareness, charging routines, household energy usage as well as other learnings around EV usage. The second part of the interview focused on their experience of the first basic version of the app interface of the smart charging function. Then they were shown an interactive app prototype with increased future content related to smart charging, home energy management, energy costs and educational content about energy, see Figure 2 (middle & right). The added content compared to the first version of the smart charging app was based on identified needs from the second set of interviews.

The participants were encouraged to think out loud while interacting with the app prototype to capture their imaginations and ideas of what kind of control of the technology they anticipated to be used in a 'smart' way. The interviews were led by three researchers participating and asking questions.

These interviews were video recorded, transcribed and analysed through thematic analysis (Braun & Clarke, 2006) by two of the involved researchers. A total of 13 hours of interview transcripts from the third set of interviews were coded and clustered into qualitatively different categories related to charging strategies and routines. These categories made it evident how smart charging strategies developed in the households through understanding firstly how the technologies worked and where they failed, how they could be adapted and changed, and secondly, how they could be trusted and evolved according to family values and priorities, and how it could be appropriated by the whole family and not depend on one person's know-how and personal interests. We clustered these categories into three themes presented in the next section. Each theme explains aspects of the life-based smart charging strategies that developed in the households when they learned to live with digital EV smart charging services: *Creative collaboration*, *Joint technology appropriation*, *Alignment of individual values and preferences.*

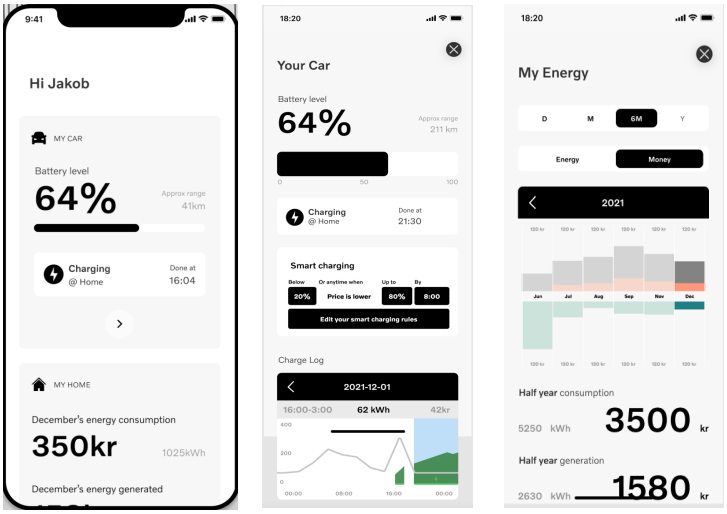

Figure 2 *Screenshot example views from the first smartphone app version (left) and the interactive app prototype probe with added content (middle and right) that was used in the third set of interviews.*

4 Findings

In this article, our ambition is to understand EV charging as it is experienced and activated by people in private households who are learning to live with charging services in their homes by asking ourselves: *How does EV charging become 'smart' in people's everyday life?*

Therefore, through our design ethnographic approach we explored what "smart" meant to the different household participants regarding their own developed EV-charging routines, we were particularly interested in what counted as smart things to do and what strategies were developed in the households to be as smart as possible in these contexts. To capture this, we asked the participants to tell us about their charging routines, habits and priorities, and if these had changed over time after having equipped their homes with the charging wall box provided by the project.

After the three sets of interviews, we concluded that all the households had gone through changes that affected the home charging routines. Some had recently changed to a fully electric car; some had used the first basic version of the smart charging function; and some had noticed how the energy spot price market had become more dynamic and more expensive, due to changing weather and the energy crisis in Europe. Through the analysis of the interviews, we developed three themes that explained how everyday life-based "smartness" was expressed, perceived and managed through the household routines. These themes pinpoint how the households a) collaborated and created new family charging routines, b) how this collaboration included learning how to appropriate the technologies together into family routines, and c) that the processes of creatively collaborating solutions and jointly appropriating the technologies afforded discussions and alignment of priorities and needs.

In the excerpts below, we use fictitious family names (see list in Table 1 above). Not all families are quoted below, the quotes are chosen to be representative of the different themes. We have coded the quotes Mrs. (Female) and Mr. (Male) in front of the family name. The researchers are anonymised as Researchers 1, 2 and 3.

4.1 Family creative collaboration

Our ethnographic interviews with the participants in the households exposed situations where family members collaborated and created ways around the limitations of new technologies to make it work in their households. It became evident that to make technology work in a household, family members took on different roles to make it work. For example, some took on the role of maintaining technology, providing technical support and tinkering with the machines whereas others made sure that the everyday

routines were done. This is exemplified in the Fredriksson household, where the husband took on the task of setting up and monitoring the smart charging technology although it was his wife that made sure the car was physically plugged in by telling him to do it:

> *R1: "But who has the responsibility that the car is charged enough for the next trip?"*
> *Mrs Fredriksson: "I'll make sure it's charging…"*
> *R1: "You make sure…and [he] does…"*
> *Mr Fredriksson: "I'm executing…"*
> *R2: "You make sure by checking with him… is it charged?"*
> *R1: "So you are the UI [User Interface], kind of the charging…"*
> *Mr Fredriksson: "I'm the app…" [Laugh]*

However, to make the charging technology system work in the flow of everyday life, both of them had to engage. In addition to this, the household members' relations to different technologies and interfaces were not necessarily fixed, in terms of who is doing what. For example, in the Fredriksson household, during the discussion of who was using the apps to check for public charging during longer trips:

> *R1: "Who is using the apps to check these things if it's available or not, or you're using the apps? [Mrs. Fredriksson nodding]…Ah, that's interesting."*
> *Mrs Fredriksson: "Maybe because I'm more interested in it. To make sure…"*
> *Mr Fredriksson: "During driving, it's also natural because sitting behind the wheel it is easier to concentrate on driving. Preparing, I did… We did a lot before we went. I looked at the third-party app and saw what the best route is, where we have the charging station and so on. So, I think we're quite prepared."*
> *Mrs Fredriksson: "But one thing… I don't, I think it's a bit annoying. Is that you have to have different apps for different suppliers. That's really annoying. Someday I'm sure there'll be just the one."*

Although in this case, it was the husband who was mostly checking apps related to charging and energy, it was in the wife's interest to make sure that they would reach their destination and prepare for when to do charging stops. In our interviews, we also noted that there are often several individual transport needs in a household and the family members reflected that it would be very difficult for the smart charging technology to estimate the needed range for the next trip depending on the next user. As the interest or the knowledge to use and set up the technology varied within a household that meant that there was someone who had to go in and set up and interact with the service to make the charging optimal and easy in the flow of the household routines. E.g., in the Bengtsson household where the husband planned and prepared the charging for his wife's longer trips:

> *Mrs Bengtsson: "But then, [he] tells me where I can charge, and he helps to make sure that I know how to charge and which… if I need to use an app or if I can use one of the cards that we have in the car."*
> *R1: "Right."*
> *Mrs Bengtsson: "And so he's planned. It's all for me."*
> *Mr Bengtsson: "I'm trying to make it a nice experience to prepare some stuff so it won't be that call of: "What? What should I do now?!?!" [Laugh]"*

This shows how the families collaborated and worked around what was available through the technology interfaces to make clever decisions according to family knowledge, routines and interest in the technology.

4.2 Joint technology appropriation

To make smart technology part of everyday life, the technology had to show or prove itself before our participants could trust it and use it smartly. The key component of this trust was to learn to not only master the technology individually but to appropriate it and understand how the technology could take part in the household's everyday life. The participants talked about how the smart charging service was expected to adapt to their routines and how they had learned to embed the technology according to their interests and values. The husband in the Fredriksson family explained how he needed to see how the algorithm was working to trust it enough to use it in everyday life:

> *Mr Fredriksson: "I think it's more like, to see that it is working and doing the optimization that you're expecting."*
> *R1: "To kind of trust?"*
> *Mr Fredriksson: "Yeah, to trust a system to know that it's feedback to create trust, what you can always rely on? This is working. Because otherwise, you don't know. So that's my preference."*

Thus, it was not enough for our participants to directly rely on an implicit algorithm. They wanted ways to first understand how the technology worked and then find ways to integrate it into their everyday lives. However, as everyday life is dynamic and changing, our participants expected the smart charging

services to easily adapt to their specific routines. Mrs Magnusson describes how it should learn her normal routines and then it was her task to tell the algorithm when she was about to do something different from the normal routine:

> *Mrs Magnusson: "Normal behaviour. I mean, normally we have kind of the same behaviour every day every week. You can follow it from Mondays to Fridays. It looks like this, weekends like that. But, I want it to learn, so I don't have to care. But, if I know that I will deviate from that behaviour, then I want some kind of way of telling it that: "Now I'm about to do something else than what you have learned"".*

However, the family members wanted the service to do more than optimising cost and time, they also expected the charging service to tell them about when something was wrong. For example, in the Jonsson household, the husband and wife described how the smart charging functions should tell them if their energy consumption deviated from the normal values:

> *Mr Jonsson: "And also for instance, a major part of our consumption is heating in the house. If the heat pump is not functioning, the electrical consumption will go up. So, if you can follow that daily you can see instead of…because we have some friends where the heat pump doesn't work so the electrical part of the heat pump was automatically put in. And that they saw a quarter after that the electricity consumption has tripled or…"*
> *Mrs Jonsson: "It's our awareness of a normal consumption level"*
> *Mr Jonsson: "So that's from the standard point of view that if our heat pump breaks down then we have a normal electrical heater that will cover up and we will not have an error on the heat pump now. So, if you see your normal consumption has increased: "Something is wrong with the heat pump, please.""*

The technology had to first explain how it worked for the participants to fully appropriate the technology, and then also how they expected it to learn and adapt to changes in their lives, as well as notifying them when something deviated from the normal.

4.3 Alignment of individual values and preferences

All the participants valued the digital smart charging service to support them in doing things in a cleverer way. However, the family members valued different things ranging from saving cost, saving time, making a less environmental impact, simplifying choices, reducing the number of steps or reducing complexity. We noticed through our ethnographic interviews that the charging technologies opened discussions about how to manage it according to different preferences, what to prioritise, and finally how to align these interests within the household. Furthermore, e.g., in the Jonsson household, the husband and wife anticipated the technology to be able to fulfil their different needs to both give detailed forecasts of the impact of different choices and as well give feedback on choices made:

> *Mr Jonsson: "And then maybe we should have a "grey one" [graphics in a charging history graph in the prototype app] predicting the next charging. If we…because we know the price, we know when we're going to have it charged, so the predicted is more or less a "grey" version [a marked timeslot in the graph showing charging history] would be interesting to understand and then I can see "oh, it's too expensive. I do not go that trip tomorrow…""*
> *Mrs Jonsson: "I think you'd like feedback on the choices I made. I would like to have it like, uh. Yes, you have made a good choice and you have saved this amount of a kWh… A thumb up!"*

The variation in how much information family members needed from the smart charging algorithm for them to judge it as smart varied. However, the amount of information needed was not necessarily fixed over time. For example, Mrs Jonsson had previously expressed her need for the smart charging function to give simple feedback on how she was doing, but further along, she explained the need to also have more information for her to act upon:

> *Mrs Jonsson: "Yeah, I would like to have information where I can make choices. To reduce the cost and…"*
> *Mr Jonsson: "…to spread out the energy"*
> *Mrs Jonsson: "..be more sustainable and have a less environmental impact. So, information that can…where I can do simple choices.*

How smart the technology worked in the families was expressed through a process where the family members aligned their interests when using the technology together, creating new family routines over time. This is exemplified by how the Magnusson family's discussion about how the newly installed solar panels made them discuss things they were not used to articulating or even thinking about together:

> *Mr Magnusson: "I've been really… At least when we get the solar panels working, we will have to know how to use them ourselves. Yeah. Maybe that is also connected to some kind of spot pricing. I'm not sure. But then we can at least try to figure out for example, when to charge the car, we are home on Saturday, and it's Sunday then maybe we should plan to charge the battery electric vehicle."*

> *Mrs Magnusson: "That I have thought about some days. Now last week about how I should charge today. Or should I wait another day because I know that they have a half-full battery? It works for another one or two days, or shall I fill it up when it is cheap? No, I have no idea. So, I was like, Yeah, whatever. But I start to think like that. I have never checked the price for fueling up the car. Never in my life…"*

In conclusion, we found out that life-based smart charging strategies developed in households' social life through processes of family creative collaboration, joint technology appropriation, and alignment and merging of interests, values and routines.

5 Discussion

At the beginning of this article, we described two veins of arguments for smart charging services as technological processes of handing over decision-making to so-called 'smart' algorithms to optimise charging in terms of cost and time efficiency (Spencer et al., 2021; Wen et al., 2020). We also described how people-centred EV user research (Henriksen et al., 2021; Jensen et al., 2019; Svangren et al., 2017, 2018, 2022), points out that EV usage and charging create processes where people learn to live, tinker and need to do ´infrastructuring´ with technologies and services in socio-technical contexts. This has impacts on the effects of the technologies (Shneiderman, 2020), where more automation technologies do not make charging complexity easier to achieve the goals. For example, in our study, when Mr Gunnarsson learned how the smart charging services worked and about its limitations to planning several days, he chose to rather set the time to charge manually himself. This example demonstrates how 'smart technologies' might not be as smart when they become integrated into people's lives. It also emphasises that to become smart and valuable in practice, the automated decision-making process must enable possibilities for people to adapt and appropriate them over time.

The results resonate with Geeng and Roesner (2019), who found that there is a need to design long-term changes in how technology is used in a social context since relationships and social power structures develop over time. Our study adds to this line of research as our findings demonstrate how 'hand-over' might instead be understood as a redistribution of initiatives, such as enabling people to customise and control automation. This opens up new possibilities for people to develop their own charging strategies.

To answer our first question; through our discussions with our participants, we learned that it was not necessarily the level of intelligence of the technology that provided 'smartness'. It was the ease for people to embed the technology into their everyday life, and evolve with it, that made it smart. Our findings show how smart charging is inevitably social to be able to be clever and the perceived "smartness" seems to depend more on how well the technology fits into the families' daily lives, rather than necessarily being technically advanced. To answer the second question, we will below discuss three implications for design that builds on these findings. We suggest that the design of smart charging benefits from affording *multi-operation ability, co-learning ability* and *social accessibility*.

5.1 Multi-user operation ability

Life-based smart charging strategies in households are social. Moreover, different users within the same household have different interests in technology (Brush et al., 2011; Geeng & Roesner, 2019; Svangren et al., 2018). Thus, the technology needs to be able to accommodate different levels of control and preferences within the same household of users. Providing multi-user operation ability is not only about providing control to anyone who uses it but also about how to handle the ownership of the technology through a "profile model" perspective (Luria et al., 2020). Everyday life consists of a mix of recurrent tasks as well as ad-hoc decisions and contingencies, and as we identified through our study, intelligent automation charging services need thus to provide possibilities for manual control or override.

In the same vein as related smart EV charging research, e.g. (Bourgeois et al., 2015; Svangren et al., 2018), we have concluded that smart charging services are used by and impact the routines of different users in a household. Therefore, the control of the technology should be designed for co-operations between multiple users and technology rather than optimising towards single-user interaction with technology. This also means that not only should the service be designed for multi-user operation ability, but it has also to be introduced as such to the homes to have an impact on established social norms and practices (Forlizzi & DiSalvo, 2006).

To bring these perspectives into the design process of digital smart charging services, engagement with multiple people within a household is needed to fully understand the need for cooperation between people and the technology and how the family routines have an impact on smooth everyday use. Our study provided examples of how ethnographic interviews with people, within a household while reflecting on a smart charging prototype, exposed these different values and routines for cooperation.

5.2 Co-learning ability

From our study, we learned that smart charging takes time to be understood and appropriated by households to be used in a 'clever' way. Following family members over a longer time demonstrated how they appropriated the charging service through co-learning processes concerning changes in their homes related to the technology during the six months between the interviews. Co-learning is often referred to as the process of a person and a computer working together to achieve a particular goal (Saunders et al., 2013). In our study, we elaborate on this view to also include other people within a household, which adds different goals to be achieved. This process was dynamic and evolving as people learned along the way. We suggest two types of involvement that need to be considered when designing smart charging services for co-learning.

Firstly, from an end-user perspective, digital technologies and services can be seen as difficult to understand due to their sometimes black-boxed and abstract representation. Therefore, users need time to learn and make sense of it. The findings showed that family members in a household might have different interests and needs for understanding the technology, which also was seen in EV user research (Svangren et al., 2018). Also, people have different learning paces affecting the appropriation and hence the perceived value of the service. This has implications for the design of smart charging services concerning how to take people's learning processes into account. 'Smart' could mean both reducing information and options as well as providing more information and options to make even "smarter" decisions. Digital charging services need to be designed in a way that invites users to learn with it, and at the same time acknowledges the different ways different users learn in different social settings and through different stages of understanding and use. Providing the possibility for people to co-learn also means accounting for the variation in knowledge and interest within a household. In addition, service design needs to make the underlying logic of aims and goals transparent enough for people to be able to discuss across different interests, ages and preferences.

Secondly, as digital technologies and services become entangled in constantly changing everyday life situations, the users anticipate the technology to evolve with them and their needs (Reig et al., 2021). The need for homes and intelligent technologies to adapt to each other was already discovered in Forlizzi and DiSalvo's (2006) work about people's relation to Robotic vacuum cleaners in homes. However, in our case with intelligent algorithms that are dependent on interfacing with other evolving technologies and services in people's homes, we want to also add implications for the design of digital smart charging technologies and services to be open-ended and always leave room for future adaptations. Without the possibility for people themselves to adapt the technology to their changing everyday and emerging needs, the technology quickly becomes limiting or even obsolete.

5.3 Social accessibility

Our study showed that the household smart charging service often was maintained by one person in the household and the rest of the family members became dependent on that person to have access and knowledge about the technology. This will not only risk problems with power structures in homes (Ehrenberg & Keinonen, 2021; Geeng & Roesner, 2019) but also making the technology 'invisible' to some people in the household in understanding or interfacing technology might lead to a lack of trust in the technology (Paay et al., 2022). As we earlier identified the need for mutual cooperation between people within a household and the technology, creates risks for friction if the appropriation of the technology is driven only by one of the family members. Therefore, we suggest that the design of smart charging services needs to account for what we call 'social accessibility', that is to enable possibilities for all household members to have access, knowledge and feel in control of the technology to ensure

that it can be fitted into the flow of the different family members' routines, needs and values. Our study addresses the need for future research to study and design for positive social norms within a household (Luria et al., 2020; Zeng & Roesner, 2019), by identifying the different values and needs within a household through an ethnographic approach to improve collaborations between household members and smart charging services.

6 Limitations

Our study has some limitations. Firstly, we had the ambition to do in-home interviews for more ethnographical depth into our interviews, however, due to the Covid-19 pandemic restrictions, seven of the households had to be performed through video meeting interviews in the third set of interviews. However, as we had several previous interviews and encounters with the participants, we had time to learn about their values and everyday lives for a longer duration of time. Secondly, the participants in the household were purposely selected according to the feasibility to install hardware in their cars and households to also be able to track qualitative data for other parts of the research project. To study and trigger the participants' interest and willingness to change charging routines, we purposely encouraged all households to choose an hourly spot price-based electricity contract as well to introduce a smart charging technology into their lives. Being part of a long-term energy research project might also have influenced the participants' interests and learning process within the selected households.

7 Conclusions

In this paper, we have presented findings from a design ethnographic study on how EV charging becomes 'smart' in the everyday lives of people in private households when they learn to charge their cars through a digital smart charging service. The households were part of a three-year industry-academia collaborative research project about end-users' experience of smart EV charging algorithms that optimised the car charging to hours when the stress on the grid and cost of energy was low or when the household generated its energy through solar panels. The findings in this paper are based on the third set of design ethnographic interviews with nine of the participating households where we used a smart charging app prototype to enable members of each household to jointly discuss values, routines and interests around what they experienced as being "smart" in charging their electric vehicles. Our findings revealed the main conclusion; the perceived "smartness" of digital smart charging services seems to depend more on how well the technology fits into the families' daily lives, rather than necessarily being technically advanced. Furthermore, life-based smart charging strategies in households are inherently social and are developed through processes of *creative collaboration, joint appropriation, alignment and merging of interests, values and routines.* This understanding led us to three implications for the design of digital smart charging technologies and services. We suggest that the service design from a people-centric perspective should afford *multi-user operation ability*, *co-learning ability* and *social accessibility*.

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