Back to the Present of Automated Mobility: A Typology of Everyday Use of Driving Assistance Systems

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Abstract

This article focuses on how car drivers domesticate technologies of automation and the way this might inform our understanding of potential shifts to a more automated mobility system. The current literature on automated mobility has mainly addressed drivers' roles in terms of their attitudes towards—and acceptance of—an anticipated shift to high-level driving automation. In this article, however, we take a step back from expectations around automated mobility to explore the domestication of driving assistance technologies and systems already in use. The analysis is built on qualitative interviews with drivers of private cars in Norway. Based on our findings, we develop a typology of user-technology characterisations highlighting three themes of the drivers' use (comfort, safety, and novelty) as well as two modes of engagements (modulation and non-use). Our analysis suggests that automation is likely to be an incremental and gradual process and that its eventual application depends on the specificities of the practices that it seeks to disrupt. Moreover, we argue that the governance of automated mobility needs to be attentive to the dynamic and unpredictable roles technology will have in processes of socio-technical change. In this context, we highlight the key roles of users in shaping processes of appropriation of both new technologies and broader innovations and argue that knowledge about technology domestication provides important insights to changes towards automation in our current mobility systems.

Keywords: Automated Driving, Domestication Theory, Driving Assistance Systems, User Studies

Introduction

Expectations that automation and digitalisation will transform current mobility systems are high, both amongst policy makers and the transport industry (Bergman et al., 2017; Haugland and Skjølsvold, 2020; Ryghaug et al., 2022). In European policy, a language centred on ideas like smart mobility, digitalisation, connectivity and automation has become integral to the articulation of mobility futures (EC, 2020). In industry, most car manufacturing companies are pursuing projects related to technologies for automation, and Big Tech has joined in. Apple is pursuing the development of its own electric car aimed towards full self-driving capabilities (Gurman, 2021), while Google's self-driving car project (now called Waymo) has communicated an ambition to enable mobility without "anyone in the driver's seat"[1] (Waymo, n.d.) for more than a decade (Poczter and Jankovic, 2014). If realised, such a transition to automated mobility might be the most significant change to the mobility system since the introduction of the combustion engine (Hopkins and Schwanen, 2017), not least due to a series of proposed benefits such as increased access to mobility for older adults and children, improved road safety and sustainability.

The research community has also embraced these expectations for automated mobility, often through mapping the road towards increased automation by addressing technical and social barriers for innovation, adoption and use of automated mobility (see Milakis et al., 2017; Hermann et al., 2018). Within earlier studies of automated mobility, major streams of work also include research into the complexity of the technological infrastructure needed to enable automated driving (see Ryghaug et al. 2022; Marti et al. 2019; Liu et al., 2020; Lipson and Kurman, 2016) and issues related to the societal organisation of automated vehicles (see Milakis et al., 2020; Milakis et al., 2017; Mladenovic et al., 2020; Stilgoe, 2020; Stilgoe and Cohen, 2021; Cohen et al., 2018). A substantial body of literature has also developed in relation to the ethics of automated vehicles, mainly focusing on analysing issues concerning accidents with self-driving cars (see Dogan et al., 2020; Nyholm and Smids, 2016; Wolkenstein, 2018; Manchon et al, 2021). Within these literatures, the use of existing technologies has only been scarcely described.

In this article, we take a step back from the grand visions of automated vehicle futures which might arguably overshadow much-needed attention to the ways that ongoing processes of automation are already shaping mobility practices in important ways. Expectations for automated mobility futures are characterised by ideas of radical change and disruption. However, as innovations meet the challenges of practical implementation, they can lose their momentum. The successful introduction of new technology requires the alignment of a broad set of interests and actors (Pinch and Bijker, 1984; Bijker 1997; Bijker and d'Andrea, 2009). Thus, understanding the roles of users of a new technology in shaping processes of its appropriation (Ryghaug and Toftaker 2014; Anfinsen et al.2019; Berker et al., 2006) as well as broader innovation processes (Schot et al., 2016) is central to theorising the potential for changes towards automation in current automobility systems (Cohen et al., 2020). Our objective is therefore to give an account of how actors work to appropriate new technologies and the struggles and frictions that can appear when new technologies meet established routines and driving patterns.

When Tesla launched its new Model S featuring an improved autopilot function in 2015, it was described as "not a car, but a sophisticated computer on wheels," pointing to the external cameras, ultrasonic sensors and robust processing power available to assist the driver in controlling the vehicle (Hirsch, 2015). It seems as though cars are being gradually transformed to reduce the gap to self-driving futures. Indeed, the Insurance Institute for Highway Safety claims that "the building blocks for that technology [driverless cars] are already out on the road."[2] Regardless of whether this vison will come into fruition, new car models are increasingly being moulded and engineered to fit visions of future self-driving vehicles. Over the last decade, drivers have been exposed to new technologies such as advanced systems that might disrupt established driving patterns, intervene in decision-making processes and interfere with individual driving preferences. This means that today´s driving practices are

already being influenced and changed by driver-related systems and technologies. Despite this, little is known about the ways driving practices are changed by the integration of such new technologies, which new practices emerge or what roles users play in making new technologies part of road-based mobility. The current transport-oriented literature largely seems disinterested in the links between contemporary technology and practice, gradual change and the automated mobility futures so often discussed.

In this article we ask how contemporary drivers domesticate (Silverstone and Haddon, 1996; Lie and Sørensen, 1996; Berker et al., 2006) technologies of automation, as well as how this might inform our analysis of potential shifts to a more automated mobility system. We do so by studying the mundane ways that automation has become part of driving over the past decade and by exploring ways that drivers make sense of, use or resist automation technologies that are already mainstream in contemporary car models. We focus on systems that automate specific functions in cars, generally referred to as Driving Assistance (DA) systems. DA systems are integrated into most modern cars to varying degrees of technological sophistication. They range from basic functions such as rear-view parking cameras and (adaptive) cruise controls that assist in maintaining a steady speed to advanced systems such as the Tesla autopilot which combines multiple sensor technologies to automate or assist driving tasks (e.g., speed adjustment, lane centring, road sign reading, parking) and actively intervene with the driver's control of the vehicle (Bengler et al., 2014). Systems with a high degree of complexity are frequently referred to as Advanced Driving Assistance Systems (ADAS), but for matters of simplification from here onward we use "DA systems" as an umbrella term capturing both the simpler systems and ADAS. Focusing on the configuration of available DA systems, we ask: how can we characterise the processes through which users appropriate such systems, and what can these characterisations teach us about the roles that users can play in a transition towards increased automation in driving?

Answering these questions provides an important corrective to mainstream narratives which suggest that a driverless society lies just around the corner. Our account instead suggests that automation is likely to be an incremental and gradual process, and that its eventual application will depend on the specificities of the practices it seeks to disrupt.

Theoretical perspective: Domestication

Our analysis is grounded in a socio-technical perspective (Sovacool et al., 2020), meaning that we are interested in exploring how relationships between technologies and their users are formed and how both the users' understanding of the technologies and their driving practices are shaped through appropriating new technologies. More specifically, our analysis mobilises domestication theory (Silverstone and Haddon, 1996; Lie and Sørensen, 1996; Berker et al., 2006), which enables a detailed understanding of the micro-practices of technology appropriation. Our analytical strategy thus stands in contrast to most social scientific research on automated mobility that does not focus on actual practices but is rather more futures-oriented and focuses on analysing systemic changes, addressing overarching transformations in mobility practices and anticipating issues related to their wider economic, technological, societal and ethical implications.

Domestication theory allows for an analysis of DA systems that zooms in on the use of technology. The approach focuses on how technological objects are transformed from something 'wild' into something 'tame' as users construct shared understandings of the technologies and how they are supposed to be used (Silverstone and Haddon, 1996; Sørensen, 2006: 46). Importantly, it evolves around an open-minded analytical process that is attentive towards the unexpected outcomes produced through technology appropriation. That is, the use and meaning of a technology are not taken for granted in the analysis but understood as something co-produced through interactions between users and technologies. The approach also renders both the technology and the social organisation surrounding it as malleable entities. Hence, new technology does not only create social change, but technologies themselves gain different meanings depending on their context of use and the specific practices they are appro-

priated into (see Ryghaug and Toftaker, 2014; Ryghaug et al., 2018; Aune, 2001; Næss, 2021).

One of the main aims of a domestication analysis is to capture the complex and extensive work that is done to stabilise the use of a new technology and to then unpack how new skills, practices and meanings are produced through this work (Sørensen, 2006). Domestication theory invites an analytical focus on three generic sets of features: 1) the formation of *new practices* in relation to the technology, such as the establishment of routines for using the technology or the development of institutions to support and regulate its use; 2) the development of new skillsets and *cognitive processes* related to taking part in the new practices; and 3) the construction of *meanings* of the technology, including the role the technology may have to the production of identities of the actors involved (Sørensen, 2006; Sørensen et al., 2000).

We approach our analysis of DA systems in a similar way. From the perspective of car manufacturing companies, DA systems have become a way to offer certain benefits such as comfort and safety to car buyers. Put differently, technology design contains a technology script (Akrich, 1992) that also includes the imagination of the user and expectations about the technology's intended use. Our interest lies in exploring what happens when these scripts meet actual users and actual uses. When the DA systems are domesticated, we should assume that the scripts are negotiated and even re-configured by users and that alterations of the intended use or entirely new and unexpected forms of use might emerge. Our focus is thus on addressing what we can theorise as the formation of new networks between technology, user and their environment that will occur when a technology is enacted in specific user contexts (Latour, 1996; Callon, 1986; Akrich, 1992). The inherent flexibility in the use-potential of technologies can be explained as the outcome of this dynamic process of network formation, which depends on already existing practices and is therefore difficult to predict or generalise (Sørensen, 1994; Pantzar, 1997).

By doing this we provide an alternative account of users compared to much of the literature on automated mobility. Previous studies' accounts of users are predominantly divided into simulator studies of driving conducted from a psychological perspective, such as using eye tracking to document attention shifts related to automated driving features (de Winter et al. 2014; Merat et al. 2014), and studies of public expectations, attitudes and acceptance of automated vehicles (König and Neumayr, 2017; Kyriakidis et al., 2015, Xing et al., 2021). In contrast, we ascribe a more decisive role to users as we focus on the active role they may take in appropriating new technologies and, relatedly, in shaping societal sustainability transitions (Ingeborgrud and Ryghaug, 2019; Ryghaug and Skjølsvold, 2019; Ryghaug et al., 2019; Sørensen, 2006;. Schot et al., 2016). Users can play important roles both as facilitators and critics of change, but this hinges on understanding what actually happens when technologies are being put to use and creating an openness to all the ways that DA systems become part of driving practices.

Methods and data

This study draws on empirical material consisting of 37 qualitative interviews with drivers using DA systems. By using qualitative interviews, we were able to collect in-depth information about users' experiences and perceptions of DA systems. The interviews were semi-structured, allowing for comparison across the material, but focused on open-ended questions that encouraged participants to share their personal experiences. While this choice of method has the limitation of not allowing direct observation of user-technology interactions, it has been valuable in understanding not only the practical aspects of using DA systems, but also the underlying assumptions, non-use practices, and sense-making processes that are crucial to the domestication of technology. Ultimately, our methodology enabled us to provide detailed insights into the complexities of using DA systems.

The interviews were conducted with people who owned cars in which one or more systems for DA were installed. The simplest cars, technologically speaking, had functions for cruise control in addition to antilock braking systems (ABS) and electronic stability programs. The most sophisticated cars had several new systems for "function

specific automations" working in combination with each other, such as adaptive cruise control, lane assisting and lane centring technologies, an automatic braking system, a rear-view camera, parking sensors, parking assistance, and road sign reading. The interviewees' cars represented a broad variety of brands and a wide range in model years, with the oldest car having been produced in 2009 and the newest in 2020. The interviewees were selected to represent a diverse demographic profile, including a variety of professional backgrounds, years of education and ages (from 26 to 75 years). An important consideration was to recruit from urban and rural areas, as we wanted to explore variations in appropriating the DA systems across different geographical and infrastructural contexts. Table 1 gives an overview of the interviewees with information about age, sex and car used. For two of the interviewees age information has not been retrieved. For the cars, manufacturer and model names are listed and also model year when this information was available to the interviewees.

We conducted qualitative analysis of the material, following an approach inspired by grounded theory (Charmaz, 2006). The objective

Table 1. List of interviewees

Interviewee nr	Age, sex	Car model (year)
IW1	40s, Male	Toyota Rav4 (2011)
IW2	50s,Male	Tesla Model S P85D (2015)
IW3	30s, Female	Tesla Model X
IW4	50s, Male	Tesla Model 3 (2019)
IW5	30s,Female	Peugeot Rifter
IW6	60s, Male	Volvo XC60 (2017)
IW7	70s, Female	Renault Zoe
IW8	40s, Male	Tesla Model 3 (2019), Mercedes B electric
IW9	60s,Male	Audi A4 (2017)
IW10	60s,Male	Peugeot 208e (2020)
IW11	30s,Male	Toyota Avensis (2015)
IW12	20s,Male	Volkswagen eGolf (2020)
IW13	60s, Male	Audi E Tron (2020)
IW14	50s, Male	Peugeot 208 (2009)
IW15	60s, Female	Toyota Avensis (2018)
IW16	60s, Female	Kia Soule (2020)
IW17	60s, Male	Audi E-tron (2019)
IW18	30s, Male	Toyota Auris Touring (2016)
IW19	40s, Female	Tesla Model S (2016)
IW20	60s, Male	Tesla Model S (2014)
IW21	50s, Male and female	BMW Hybrid
IW22	Female	Peugeot 508 (2012)
IW23	Male	Nissan Leaf (2016)
IW24	50s, Male	Tesla Model 3 (2019)
IW25	40s, Male	Opel Ampera (2017)
IW26	20s, Male	BMW 318 (2016)
IW27	70s, Male	Mitsubishi Outlander (2017)
IW28	50s, Female	Jaguar F pace (2019)
IW29	20s, Male	Tesla Model 3 (2019)
IW30	60s, Female	Mitsubishi Outlander (2017)
IW31	40s, Male	Nissan Leaf (2018)
IW32	60s, Female	Nissan Qashqai (2015)
IW33	20s, Male	Jaguar I-Pace
IW34	40s, Male	VW e-Golf (2020)
IW35	50s, Male	Tesla Model X
IW36	50s, Male	Opel Ampera E (2018)
IW37	70s, Female	Mitsubishi Outlander

of our analysis was to develop an empirically grounded understanding of the users' interactions with the DA systems that could provide a basis for theorising processes of automated driving and the users' roles in these processes. The analysis was conducted in two main steps. The first step was geared towards developing a rich empirical characterisation of how the drivers were using the DA systems. We asked descriptive analytical questions: In relation to what aspects of their driving were DA systems used? How did users see the benefits and challenges of using DA systems? How was the use of DA systems shaping their driving? We also focused on developing insight into the relations that were formed between the users and the technologies. This was done by identifying dimensions in the interviewees' use of DA systems that cut across the identified main themes. The second step of the analysis was aimed towards generating an understanding of the domestication process as a whole in relation to DA and cars, focusing on the main features of technological domestication highlighted by Sørensen (2006).

A typology of DA and user interactions

In the following analysis, we have first developed a typology of DA systems and user interactions based on themes identified in the users' accounts (comfort, safety and novelty) and the modes of use identified across those themes (modulation and non-use). Second, we discuss our findings in terms of key features of the domestication process, asking: What new practices can we observe in the use of DA systems? What types of skillsets are developed to stabilise the use of the DA systems? How do drivers ascribe meaning to the technologies, and in what way do the technologies play a role in the formation of identities among the drivers?

DA for comfort

Unsurprisingly, comfort was one of the most frequent themes in the interviewees' accounts of using DA. When talking about DA in this context, the drivers made sense of the technologies in relation to mundane, everyday aspects of their driving. The technologies were "just there" as parts of their vehicle, and they used them whenever they felt the systems could offer increased comfort. For most of the drivers, DA systems had not been important in the decision of which car to buy; neither did they feel that the DA systems impacted how, when or why they used the car. Rather, their car use was generally presented as routinised, based on what they presented as stable driving practices and travel habits. The applicability of DA technologies was thus dependent on the technology being integrated into this existing landscape of everyday use. For example, adaptive cruise control and lane assistance were typically used to make long distance driving less tiring by delegating certain driving tasks from the driver to the car. One driver explained:

> […] it just makes driving a bit more comfortable. I have noticed that when I use the accelerator in a normal car [without DA], my foot actually starts to hurt, but if you use DA you will relax much more. You get less tense and you have a more comfortable driving experience. (IW2: 50s, male, Tesla Model S P85D 2015)

Another way DA was used to increase comfort was to assist in situations where the technologies alleviated the driver's stress, like using a rear-view camera to park the car accurately:

> I have become completely dependent on using the rear-view camera; you know using the sensors for backing the car, the rear-view camera, the alert system for parking and things like this when you are driving and are about to park. The combination of the alert system for parking, the sensors measuring the distance and the rear-view camera makes parallel parking so much easier. (IW6: 60s, male, Volvo XC60 2017)

As the quote illustrates, domesticating DA as comfort was dependent on the driver experiencing a benefit to their driving from the systems. Also, there needed to be a good match between the DA's formatting and the driver's existing driving patterns. To be used, the DA systems thus needed to have a low degree of disruption and build upon the ways that the drivers were already using the car. In sum, this means that the DA systems played a subordinate role in the driving practices and was

rather experienced as technologies that provided incremental improvements to the comfort of driving. Importantly, this type of mundane use was prominent among users of older and simpler DA systems as well as advanced DA systems.

Comfort: Modulation and non-use

We are not only interested in exploring the common themes in the drivers' DA use but also in understanding the domestication process in light of the drivers' engagements with the technologies. That is, the drivers' accounts also show how this domestication drew on a continuous interaction between the user and the technology. Moreover, the drivers were constantly modulating the technology to make sense of it and adapt its use according to individual preferences, driving patterns and driving environments. Many pointed to obvious limitations in certain DA systems because of their dependency on clearly visible road-surface markings and stable driving patterns. This finding is also supported by previous research demonstrating the diverse attachments of autonomous vehicles, like reliance on infrastructure (see eg., Stilgoe, 2018; Tennant and Stilgoe, 2021; Ryghaug et al., 2022). Using DA was thus dependent on the driver's ability to interpret the driving environment and the driving patterns of other cars. For the general use of DA, this meant that the drivers also had their own individual preferences between when they saw the benefit of using DA and when they felt the technologies generated more annoyance than support. For example, some drivers actively chose to use adaptive cruise control for most of their driving, while others often avoided it, such as in situations where the road infrastructure was poor or where driving patterns could be unpredictable and create difficult situations. The threshold was quite low for when some drivers experienced the DA systems as generating more dis-comfort than comfort, showing they expected DA systems to be easily matched with their existing ways of driving. The following quote illustrates this form of "on and off" use:

> If you are driving on a country road and you reach a turn, then the car wants to slow down and I find it difficult to adjust the level of the system to something that feels comfortable. I would say if I am driving on a country road, and driving long distances, I would only use adaptive cruise control if there is traffic and I am stuck behind other cars. (IW17: 60s, male, Audi E-tron 2019)

The use of DA systems was also dependent on the driver's interest, willingness and ability to engage with the technologies. Some interviewees would present themselves as "too lazy" or not "interested" or "curious enough" to figure out how the technologies worked or how to operate them. As a result, they chose instead to dismiss them and to "only use a small portion of what the car has to offer" (IW28; 50s, female, Jaguar F pace), arguing that they were not willing to invest the time needed to figure things out when they could drive "just fine" without them. In these instances, the more advanced the DA systems were the more unapproachable they could appear. This means that comfort was not only relevant for the drivers' domestication of the technology but was also used as an argument for dismissing it.

This type of selective use—or rather, non-use—could also be the result of a driver experiencing a mismatch between their personal driving style and how DA systems enforced a certain structure upon their driving. One rural-based interviewee explained that she liked to drive slowly to enjoy the landscape and that DA, like cruise control, would not allow for such idiosyncrasies in her driving pattern:

> We have so much beautiful nature and then I slow down and I want to be able to look at the nature, so I drive I little bit like that…I cruise around for myself and enjoy the nature. My driving is not straight forward in the same speed, with a lot of traffic on a long highway. (IW15: 60s, female, Toyota Avensis 2018)

The drivers in these cases did not incorporate the DA systems into their driving because of an experienced friction between automation and individual preferences. Such instances of non-use point to diverse valuation practices among the drivers that were difficult to generalise and accommodate through automation. While the drivers experienced that automation algorithms prioritised efficiency, they gave accounts of how driving could fulfil roles beyond the practical task of transporting them from A to B and rather be

a source of enjoyment (see e.g., Edensor, 2003). It is worth noting that interviewees ascribing to established gender identities could also be shaping the domestication process in this respect, like stereotypical claims about masculine fascination for technology. Our material provides support for this, e.g., one female interviewee stated that she did not use certain DA functions, but then added "but my husband always does" (IW3, 30s, female, Tesla Model X) . However, recent studies on the adoption of electric vehicles in Norway suggest that traditional gender roles in relation to cars are evolving (Anfinnsen et al., 2019). Furthermore, automation is expected to further influence the gendering of cars, underscoring the need for a nuanced investigation of the relationship between cars and gender (Weber and Kröger, 2018).

DA as safety

Safety was the second main theme identified from our interviews. Some drivers explained that the DA systems outperformed their own cognitive abilities, and so DA was understood as augmenting their driving to improve their safety. This was often attributed to more advanced DA systems that could automatically stop the car or slow down its speed when sensing an obstacle such as a pedestrian stepping onto the road or a car in front performing a rapid brake without warning. In these situations, many referred to the DA as an "added layer of safety" responding faster than themselves, without distraction. One interviewee explained enthusiastically how his car was "reading situations on the road better" than himself (IW24, 50s, male, Tesla Model 3 2019), while another told about a situation where the car had saved her from a potentially big accident:

> I was looking away from the road for a few second to adjust the radio, and then the car suddenly beeped very loudly! Someone had braked in front of me, without me noticing it. If it had not beeped I very well could have driven right into it […] It adds a feeling of safety to know that the car will tell me if something is in front of it (IW19; 40s, female, Tesla Model S 2016)

The use of DA systems was also experienced as enhancing safety by freeing drivers from tasks such as keeping the speed limit by checking the speedometer, adjusting the speed, and changing gears. This allowed drivers to pay full attention to the road. Some claimed that this made them substantially "less tired" from long distance driving when using complex DA systems like installed in the Tesla models (IW8, 40s, male, Tesla Model 3 2019). However, one interviewee also explained how a quite simple function like automated light adjustments allowed her to focus on road conditions which increased safety.

> I can concentrate on the road conditions. When it is dark outside during winter in Norway it is very tiering to keep switching on and off the lights while focusing on driving on narrow roads at the same time […] and if you control it manually perhaps you want to keep the full beam light on for longer than you should (IW21: 50s, female, BMW Hybrid)

For many, the question of delegating tasks to technology also sparked reflections on how using DA affected their own attention. This led to more critical remarks that the technologies decreased their attention towards the road, as DA systems enabled them to multitask (applying lipstick or unpacking lunch and eating) while still feeling safe. One driver warned about this practice:

> I do not become a better driver, I become a more passive driver. It is not like you increase the level of driving by using new technologies, you can instead become less aware of actually driving. (IW18: 30s, male, Toyota Auris Touring 2016)

As shown here, when speaking about safety, the interviewees often engaged in an explicit reflexive process where the drivers showed awareness of benefits of the DA systems to their driving and also potential down-sides of using the technologies. Interestingly, this points to how the users experience of safety was based on balancing the need for support and their own participation in driving when using more advanced DA systems.

Safety: Modulation and non-use

Just as the comfort provided by DA resulted from the drivers' modulating efforts, the feeling that DA improved safety tended to emerge as a result of driver-technology interaction over time. Respon-

sibilities were little-by-little delegated to the DA systems, gradually building trust in the technology. For example, many interviewees described being anxious when using lane assist technologies or adaptive cruise control for the first time, as well as feeling a lack of control or that the car had a will of its own when it automatically adjusted itself on the road. Several also experienced episodes where the car either "phantom braked" seemingly without any visible obstacles in the road or steered them into potentially dangerous situations because of poor road marking. As a result of such experiences or just hearing others talk about them, many had a conscious relationship with the technologies in which they gradually learned when and how to use them and were alert to adjust the technology whenever needed. In these instances the interviewees talked about "thinking ahead of the car" (IW4, 50s male, Tesla Model 3 2019), or like one interviewee explained

> I never keep my foot far away from the pedals, and if I feel like it does something strange I adjust it myself […] We Tesla drivers are part of gigantic product development process where they track everything we do so the systems can learn from it (IW8: 40s, male, Tesla Model 3 2019)

Another example of gradually building trust concerned the use of a camera to assist in parking and reversing the car. Several interviewees explained how they found it difficult to completely trust the camera; some often felt the need to complement it by looking in the mirrors or turning their head, just to make sure they were clear of any obstacles. In this way, the use of the DA systems did not replace but rather added elements to existing practices and using the technologies was expressed as a processes of "learning to trust them" through gradual adaption (IW16, 60s, female, Kia Soule 2020) and also gradually incorporating new elements into the ways they had been trained to drive. These aspects of building trust, experience and overlapping practices highlight the temporal dimension of domestication and provide challenges for researchers who seek to understand the acceptance of automation because this, too, can be assumed to emerge over time with experience. Systems that had been a part of cars for many years, such as ABS, triggered less reflection; they were perceived as natural parts of the car and were relied on by the interviewees in their driving. Their own skills to complement these technologies, such as cadence breaking or correcting a skid, were perceived as gradually degrading.

Importantly, trust in their car's DA systems was not established for all the drivers, and we also observed non-use in relation to safety. Some chose to not use DA systems because they were not willing to "share" their control of the vehicle with the technology or they felt like the technology was not accurate enough to be of practical use. The perception of control has been presented as an important component in drivers' attitudes towards DA systems, often referred to as the "loss of control" argument in human-machine cooperation. However, it has also been difficult to confirm this argument empirically (see Weyer et al., 2015). While our data shows that the drivers in general felt at ease with using DA systems and that most issues were related to practical applicability instead of safety, the loss of control was still mentioned as a source of concern. On a related note, many felt that they did not understand how the advanced technologies made decisions, and therefore would not delegate control to them. This indicates relations between the level of DA advancement, technical understanding, practical experience and trust. One driver, who was normally using an older car, but had been trying out a newer model with advanced DA described this feeling of insecurity in using advanced DA systems as such:

> It was very special to let go of the car and leave everything to the car all the time. You do not know what lays behind the choices that the car makes, what if the car does something that you would not want to happen? (IW11: 30s, male, Toyota Avensis 2015))

Even though many of the drivers were actively using DA systems in ways that automated certain aspects of their driving, their perception of responsibility remained stable. Building practical experience with the technologies and becoming sensitised to their shortcomings seemed to produce a reflexivity among drivers concerning the relationship between themselves and the car. Most interviewees strongly believed that

the responsibility was still the driver's, even if a malfunction in the DA system contributed to an accident:

> The responsibility always lays with the driver, there is no discussion about that in my opinion. You cannot blame the technology when you are driving a car. It is the driver who is responsible, these are only tools meant to assist you (IW7, female, 70s, Renault Zoe)

In this way, the driver´s understanding of responsibility is linked to a practical understanding of the technologies in use, the contexts in which it is used and how it affects the driving. Moreover, their understanding of responsibility in relation to new DA technologies is derived from existing practices of responsibility for car driving that are stabilised through traffic laws and other institutions, such as traffic schools. Importantly, we observed that both drivers of cars with advanced and simpler DA systems posed strong claims about the driver being responsible in case of accidents.

DA as novelty

The third main theme in the drivers' accounts of using DA systems was novelty. Through the drivers' discussions of novelty, we can see that their domestication of DA was linked to ideas of technological progress—that DA was something new, exciting and cutting edge—and this accordingly added value to their driving experience and their car. This means that the domestication of DA was not only linked to practical aspects, such as DA systems making driving easier or more comfortable, but also to sensations like excitement and enjoyment of driving (Næss et al., 2023).

In focusing on the aspect of novelty, the interviewees foregrounded the technologies, portraying them as futuristic elements that distinguished their current car from their previous cars. Novelty was also closely tied to a more general interest in technological development, and the drivers´ accounts of using the most advanced DA systems were sometimes accompanied by an expressions of fascination for technological progress:

> It is almost out of this world, you know. I hope every car gets safety functions like this, not necessarily the autopilot function, but, so many accidents could have been avoided if the machine had taken over. It is absolutely genius. I am not skeptical at all, I know a lot of people are skeptical, but I am not. I think that the machine, all things considered, always is smarter than you, who can be a bit unfocused, or maybe you are getting a text. (IW24: 50s, male, Tesla Model 3 2019)

Our data on the DA-user interactions thus show many similarities to previous literature's identification of important features among early technology adoption and the particularly prominent role of affective aspects of technology use in early phases of technology domestication (see Schot et al., 2016; Pantzar, 1997). Moreover, the phase-in of new technologies in Norway, such as energy-saving technologies in households, has drawn strongly on policy strategies focusing on the importance of such early adaption in stimulating market adaption.

Novelty: Modulation and non-use

As in the case of comfort and safety, domestication through novelty was based on an interaction between the user and the technologies. However, the interaction was described more explicitly as an active involvement with the DA systems and based on a feeling of participation. For example, several interviewees experienced their car doing unexpected things that potentially could bring them into a dangerous situation, but they showed a marked leniency towards these malfunctions, explaining that they knew they were dealing with immature technology that had to be developed further.

> I have to confess that something could have gone terribly wrong in the situation where the car got confused about the road markings in the overtaking line. […] But nothing happened: the wheels ended up outside the lane, but I corrected the car, and got a very big skid so the car almost drifted sideways, but then the car corrected itself. My heart beat a little bit faster, but that was a reminder; ´you cannot relax here´, this is beta testing, beta car…. the technology is beta and you cannot expect that everything works smoothly. (IW4, 50s, male, Tesla Model 3 2019)

Some drivers also saw themselves as having an explicit role in this development, taking on a role not unlike what Schot, Kanger and Verbong (2016) have described as 'user-innovators.' These drivers noted that their experiences could be crucial for improving the systems. Systems like those installed by Tesla that continuously collect data from the drivers were important in making this role of participation explicit, and thus also making the driver attentive and reflexive about how they used the technologies and their malfunctions.

The interaction between the users and the technology was also shaped by how the drivers imagined the intelligence of the DA systems; some related to the technology almost like a pet or a child, talking about "teaching" the car how to behave properly in certain situations. These interviewees referred to the process of using DA as a continuous process of learning, for themselves and for the car, or explained that dangerous situations could be "spooky" but also "part of the game" when using new technology:

> So unwanted and unexpected situations do happen, like when the car turns too much to the right and then panics when it detects it, and then all of a sudden make a sharp turn to the left again. Then I use my hand actively and help the car to understand and I sense that each time, before a new update resets the process, the car is learning. The car understands that it is supposed to keep to the left at that exact GPS point on the map. (IW4: 50s, male, Tesla Model 3 2019)

Interestingly, while a fascination for the new was an important theme in domesticating DA, the aspect of novelty was also presented as a reason for choosing not to use the technologies. In these cases, the drivers argued that they were not skilful enough, too old or not interested enough to introduce new elements into their already routinised ways of driving. Moreover, some argued that they preferred the "proper" fully manual way of driving, like they had been taught in traffic school. In discussing this aspect, interviewees highlighted the more emotional or tactile aspects of driving, such as explaining how they enjoyed shifting gears themselves and being fully in control of their vehicle or that driving could be something joyful and not simply a means of transportation. One interviewee described the feeling of using a car without DA as:

> It is that fantastic feeling for a man in my age, to be able to feel that I am back in a car that really is a car, and not a computer. There are feelings of joy connected to driving something where you sense that it is you who are making the decisions and not a computer that tells you how to drive at all times […] You drive the car; the car does not drive you. (IW10: 60s, male, Peugeot 208e 2020)

Such reflections illustrate the different meanings a car can have in people's lives and the social dimensions influencing car driving that can reach far beyond a narrow understanding of the car as a mean of transportation (se eg. Pearce, 2017; Jain and Lyons, 2008; Edensor, 2003). The introduction of new technologies to automate driving in this context seems to be understood as a source of detachment from driving and experienced as something cold and emotionless.

A characterisation of technology and driver interactions

Synthesising across the three themes discussed above, we generated a typology of technology-driver interactions. These interactions can be categorised according to their thematic focus (comfort, safety and novelty), with two dimensions (modulation and non-use) cutting across the three themes. This means that the domestication process is linked to certain thematic areas but also dependent on the driver's active involvement in modulating the technology. Moreover, the same thematic areas of domestication can be negated and presented as causes of non-use. The two dimensions in the typology thus point to the dynamic character of DA use, as the users show different modes of interacting with the DA systems within each of the themes. Table 2 presents an overview of this typology.

The typology demonstrates the diversity in DA use and illustrates that domestication of DA depends on more than the driver's acceptance of the technology; it depends on the formation of a complex set of relations between drivers, technology, road infrastructure and natural environments.

Table 2. A typology of technology-driver interactions

Themes	Modulation	Non-use
Comfort: Using DA to make driving more comfortable and less stressful in certain situations. Using DA to relieve the body from physical and mental stress. Match between automation and individual preferences.	Adapting DA to specific driving contexts / individual preferences. Modulating DA through active user involvement. Perceiving functionality as a product of DA and user interaction.	Dismissing DA because of annoyance, poor functionality or technology avoidance. Experiencing mismatch between DA formatting and personal driving preferences. Drivers not interested in investing time into the process of adapting the technology.
Safety: Using DA as an added layer of safety to existing driving practices. Experiencing DA as augmenting the driver's skillset. Drivers present a belief in DA's capabilities to outperform human cognition. Using DA to moderate personal driving patterns like staying within road speed limits.	Users negotiating relationships of trust with DA systems in terms of delegating driving tasks. Placing importance on human presence and intervention to back up technological malfunctions and serve as precautionary measures. Gradual processes of adaption with overlapping practices of DA use and pre-DA habits.	Experiencing a lack of autonomy while driving and limited insight into the car's decision-making process that is perceived as scary. Drivers not willing or interested in delegating control or engaging with the technology in order to adapt the use of DA to specific driving contexts.
Novelty: Using DA as something that adds excitement and enjoyment to car driving. A focus on the technologies in themselves, and linking their use to processes of exploration. Drivers demonstrate curiosity related to the functionality DA can provide.	Experimenting with the technology and testing its limits to map functionality. Perceiving malfunctions as opportunities for improvement. Drivers perceive themselves as active participants in the technological development.	Dismissing new technology based on nostalgic ideas of driving. Perceiving new technology as something that interferes with established driving practices. Displaying a focus on driving as a cultural practice and highlighting the enjoyment of non-automated processes. Perceiving DA as something too difficult to learn or not necessary given how they use the car.

Domestication of DA systems: Practices, skills and meaning

In this section, we discuss use-technology interactions by focusing on the three main features of domestication processes: emergent practices, skillsets and meaning-making (Sørensen, 2006).

Emerging practices

Building on the analysis presented above, we can argue that the use of DA did little to intervene with the interviewees' routinised ways of using their cars, in terms of when they used the car or what role the car played in their daily life. These routines were stabilised through the general organisation of their life, such as the distance they lived from their workplace, if they had a cabin outside of town or if they had kids that needed to be driven to different types of activities. To the extent that the use of DA affected these routines, it was only in minor ways, such as making daily car rides more comfortable or resulting in the car being the preferred travel mode for long distance travel due to increased comfort. Some also described a new practice in which they found themselves driving just for the sake of the excitement of testing new technologies.

Thus, rather than influencing practical aspects of using the car, the use of DA systems was closely tied to existing practices of driving; its appropriation was built upon these established practices. This meant that the changes introduced through DA were experienced as a continuation of established driving practices. The DA introduced new technological elements that incrementally modulated their driving behaviour, such as cruise control functions making their driving style less aggressive. Importantly, the user's active involvement to support the technologies was a key element in stabilising the use of DA. The use of DA can thus be described as a hybrid practice, partly consisting of the driver's own cognition and driving skillset and partly the technological automation enabled through DA systems.

Skillsets

As part of this hybrid practice, the skillsets needed to successfully appropriate the technologies largely entailed merging already-existing driving skills with the processes of automation provided by DA systems. The drivers rarely problematised the process of learning about the functionality of the technologies, instead presenting it as a straight-forward process based on an intuitive "learning-by-doing approach" that only demanded a certain level of willingness to engage with the technologies. The more important skillset for appropriating the technology was thus a meta-cognitive skill: an ability to evaluate the contexts in which DA systems could be used. This included making individual judgments about advantages and disadvantages based on driver preferences, learning what driving situations could be difficult for the DA systems to interpret and identifying situations where the technologies would need "help" from the driver. Through using the DA technologies and being exposed to a variety of situations, this meta-skillset is developed by drivers and becomes a key component in building a relationship of trust between the drivers and the DA systems.

Meaning-making

For the most enthusiastic users, the DA technologies were part of performing an identity as a progressive and technology-optimistic driver. This shaped the way the drivers ascribed meaning to the technologies, focusing on them as beta technologies and highlighting that some technological features were immature. This way of giving meaning to the technologies was important for how these drivers positioned themselves in relation to the technology and how the technologies were domesticated. To understand the technologies as "still in development" gave room for a permissive attitude towards the malfunctions of the technologies and also for understanding themselves as participants of what they presented as an ongoing "experiment" towards increased automation in driving. Importantly, such willingness to participate in the technology development process, to become what Schot, Kanger and Verbong (2016) and Kanger and Schot (2016) refer to as user-producers, has been shown to be a crucial resource in the dispersion of new technologies. Through their tinkering, user-producers play a key role in adapting technologies to specific user contexts. This type of behaviour also aligns with Panztar's (1997) description of early encounters with technology as often characterised by sensations of joy and happy experiments; the enthusiasm expressed by some of the drivers appears to be an important resource for domesticating new DA systems.

This fascination with the novelty of the technologies is not only important for establishing an emotional tie between the driver and the technology, but can also be seen as a resource for more general reflections on driving practices and human-technology interactions. For the interviewees, experiencing new DA systems controlling the car in certain situations sparked reflections on the limitations of their own cognitive abilities. This reflexive process was also prominent among the drivers who did not share this enthusiasm for the new technologies and had more cautious or anxious approaches to appropriating the technologies. Using the technologies and experiencing a lack of trust in the technologies' decision-making or friction between the automation's formatting and their individual driving preferences became a disruptive element in a routinised way of driving. For our interviewees, this generated reflections on the technological complexity of automating driving, the differences between human and technological decision-making and the role of infrastructure in driving.

Conclusion

Many European countries are now impatiently trying to set new trajectories for their mobility systems. In this context, visions of automation have become powerful attractors for policy makers in search of solutions to issues related to sustainability, safety, mobility access and local industrial development. However, transitions always entail grappling with trade-offs and unintended consequences (Kemp et al., 2007; Skjølsvold and Coenen, 2021). Hence, there is a need for careful governance approaches to address the wider societal implications of automation as well as how drivers and passengers will be affected by such

developments (Hopkins and Schwanen, 2018). Our study represents an effort to take a step back from the promises of automation and direct our gaze on automation technologies already in use. By doing this we have, first, wanted to distance ourselves from hyped industry visions of automation's rapid upheaval of the transport system and rather work to understand the incremental steps being made towards automation and, second, highlighted how these incremental changes are gradually becoming part of life on the roads in different ways. Our study points towards a set of concrete findings concerning the technologies we have studied, but also towards a set of generic processes involved in socio-technical change. It seems unlikely that large-scale transport automation will be able to by-pass such processes in which domestication plays a key role.

By exploring the use of DA systems through the lens of domestication theory, we have shown how a driver's understanding of DA systems and, accordingly, their use patterns are shaped by the specific and complex contexts the technologies are adopted into. This is an important empirical insight that should be integral to how we understand and aim to initiate processes of change. This perspective also opens the way for a more fundamental argument about the unpredictability of implementing new technologies for driving automation. Domestication processes are shaped by the socio-technical arrangements that the technologies become part of, often causing unexpected outcomes. As policy makers and industry now seek to transform transportation through automation, this raises the central question of how one could try to predict potential unintended consequences.

In our study, the drivers' accounts of using DA systems show rather modest impacts on how the car was used in everyday life. This is an important observation in relation to the popular visions of driving automation that often point to possibilities to fundamentally disrupt current mobility practices. These visions stand in stark contrast to how our study shows DA systems are used today. Rather than disrupting user behaviours, DA systems are today aimed towards sustaining existing practices by making them more comfortable, less cognitively challenging, less stressful and safer.

Interestingly, our study also shows that the tolerance for friction between DA systems and the driver's established ways of driving is rather low. Too much interference or change often had the consequence of the technologies not being used. The domestication process was accordingly dependent on a good match with established ways of using the car. To further introduce automation into driving as a mean to reach sustainability goals, it is thus important to find ways that can facilitate more substantial disruptions in today's mobility practices. There is considerable political potential in mobilising DA systems to make a constructive contribution in facilitating more sustainable driving practice but this would require new design practices as well as engaging actively with existing environmentally-oriented elements of contemporary societies.

As an overarching observation, this study highlights the importance of facilitating experimentation when introducing new technologies, allowing users to build relations with the technologies. The trust some of the drivers developed towards the DA systems was not a given but rather the result of the drivers gaining experience through their use. Moreover, the use of the DA systems also appeared as a source of reflexivity among the drivers, both in relation to the capabilities and responsibilities of the technologies and to their own driving behaviours. Users can in this way be seen as important resources in a transition to new forms of mobility; analysis of the use itself provides crucial knowledge for policy makers that can unpack and create awareness towards the unpredictable ways that technologies for driving automation can become part of the ways we drive. In sum, the domestication perspective employed in this study leads to increased attention in how aspects related to experimentation and use over time can be key elements to explore in the transition towards automated mobility, not only to map fault lines and drivers for processes of change but also to actively enable new and productive relations between drivers, technologies and environments.

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Notes

1 See the Waymo website, https://waymo.com, for information on the Google self-driving project.

2 See communication from Russ Rader, Senior vice president at the Insurance Institute for Highway Safety retrieved from https://abcnews.go.com/blogs/business/2013/09/the-next-step-to-driverless-cars