Human-Centered Design of Privacy Controls for Autonomous Vehicle Data Sharing

By Dr. David O'Sullivan

Associate Professor of Computer Science, University College Cork, Ireland

1. Introduction

We present a human-centered design of privacy controls for AV data sharing, motivated by participants' preferences from our study. The design allows users to set access controls based on the timing and initiation of any given particular data need.

Envision that your vehicle is fully autonomous, and let's say this happened to you. To improve your memory and prove that the events were not the cause of the crash, would you be comfortable with data sharing from your vehicle? Study participants preferred to have control over who has the ability to access AV driving data. The most common place for AV data access wants requirements during emergency situations.

This research investigates human-centered design of privacy controls for AV data recording and sharing capability. We conducted a study with the general public. Study participants reviewed a news article discussing an accident in which an autonomous vehicle was involved. Data from the vehicle helped law enforcement prove the driver's innocence. The driver, however, has suffered head trauma and has no memory of the events that occurred leading up to the crash.

The variety of potential uses of AV-related data means that data generated by these vehicles could be in high demand. Despite the potential for data sharing, however, there are practical and ethical reasons why there should be limits on data sharing. Most likely, AV occupants have privacy expectations, and so would want limitations to data collection and sharing to protect their privacy.

Autonomous vehicles (AVs) are equipped with multiple sensors that collect data from surrounding environments. Data from autonomous vehicles has a variety of potential uses. It could be used for better coordination between vehicles, for law enforcement, legal disputes related to crash events, traffic management, parking, and emergency services and management. Because of its great potential personal use, the question of who can access data from autonomous vehicles is of obvious interest.

1.1. Background and Significance

Autonomous vehicles (AVs) generate a great amount of data that can better guarantee AVs' security, provide benefits to various entities, and support future businesses. Nevertheless, sharing privacy-sensitive AVs data introduces risks and challenges such as unauthorized surveillance, denials of service, and liabilities for AVs manufacturers because AVs' data records context, driving features, passengers' private information which will increase AVs' privacy threats and to exceed autonomous vehicles-controlled environment. Enabling AV owners, drivers, and passengers to control the sharing of this data can mitigate the risks imposed by data sharing without disproportionately impeding the deployment of AVs. Traditionally, privacy-preserving solutions for vehicle data sharing are mostly designed in a centralized framework and thereby trust a trusted centralized server. A disadvantage of the centralized framework is that entities have to trust the centralized server entirely, and the system with the centralized server is not robust to server's misbehavior. Therefore, data sharing occurs only within the context of secondary uses that are explicitly conceived by service providers without a very strong security-aware culture and fail to consider user privacy. However, it is complicated to design a privacy-preserving decentralized vehicle data sharing platform because of the distinct functionalities and security/privacy requirements of different autonomous vehicle stakeholders. Online autonomous vehicle data sharing systems present unique security and privacy risks that are not addressed by existing techniques.

1.2. Research Objectives

The main objective of this research is to investigate new methods to ensure vehicle operator privacy if the vehicle owner or the service provider decides to share certain data with another organization using a vehicle. While privacy can be maintained by not sharing the data, the ability to share data is critical to enable public and private sectors to leverage autonomous vehicles for services. For example, data streams such as lateral and longitudinal accelerations, steering wheel angle, and camera images may be shared. With these arbitrary data potentials in mind, the important objectives are to design the privilege delegation mechanism, to establish the knowledge of what human abilities to incorporate in the selection process, and to understand the kinetics of delegation, overriding, and revocation. The research objective defines the design boundaries in terms of the technical, physical, and observational limitations that the system must overcome. The effort is to contribute design principles and guidelines for interactive user interfaces that are able to accurately reflect human characteristics and meet human privacy and communication requirements.

2. Autonomous Vehicles and Data Sharing

Consequently, sensitive situation-based contextual information can be collected about both the vehicle's owner/driver and others who share the public roads. To achieve their intended operational goals, there is a need to analyze, process, and share the data both within and across vehicles. This publication focuses on the privacy implications of sharing the data and proposes new privacy control design prototypes that reduce the implications of sharing and achieve the right balance between the societal benefits of data sharing and the privacy of the vehicle drivers and passengers. Informally known as autonomous vehicles (AVs), these vehicles can operate with minimal or no human input making them suitable for various transportation tasks like transportation of passengers, goods, freight, containers, or equipment within and across urban or semi-urban environments.

In 2004, the US Defense Advanced Research Projects Agency (DARPA) set an ambitious goal for the automotive community to make effective autonomous ground vehicles that can complete an off-road driving challenge through a desert environment within 10 hours of time. This challenge jumpstarted the connected vehicle/autonomous vehicle industry, and many notable contributions from industry leaders have enabled recent advancements in autonomous, semi-autonomous, and connected vehicle technologies. However, security and privacy challenges are inherent in the operation of these autonomous and semi-autonomous vehicles. Their operations collect huge and heterogeneous data from the vehicle's surroundings through various in-vehicle and exterior sensors that include different types of cameras, lidars, radars, microphones, GPS among others.

2.1. Overview of Autonomous Vehicles

Use of privacy-sensitive data of vehicle movements gathered by the vehicle or by any receiving autonomous vehicle control services from data from other similar vehicles has received particular attention. Developers assert that the use of this data will be voluntary; that is, that drivers will choose to opt in to sharing such data with a receiving autonomous vehicle control service only if they accept the benefits of doing so (reasoned). They also say that sharing like vehicle data is essential to deliver the safety and traffic benefits they expect to flow from widespread use of autonomous vehicle technologies. Such data is necessary so that each vehicle's perception system can build a precise visual model of the road and other vehicles therein, so that self-driving vehicles can safely navigate any environment in which they may be used.

The partnership of the digital and automotive industries has begun to produce fully autonomous road vehicles; that is, vehicles in which the human driver is intended to be completely irrelevant and that could safely operate anywhere that normal human drivers can. Developers claim that these vehicles will be both safer and also a boon to privacy and a means of freeing time now wasted by driving for more productive and agreeable activities. Two security and civil rights concerns of these vehicles have already attracted great interest. Questions about the safety of self-driving vehicles are being forced into public debate, at the same time as concerns about the use of these vehicles to infringe drivers' privacy rights receive frequent media attention.

2.2. Types of Data Generated by Autonomous Vehicles

Structural sensor data. Radar, lidar, and ultrasonic sensors help the vehicle's system to better understand the structure of the environment around it. Radar can give insight into the relative velocity of a bounding pedestrian, lidar can provide a 3D point cloud map of a non-stationary object, and ultrasonic sensors can help detect objects in the vehicle's blind spots.

Images and videos. Cameras, whose orientations range from the rear and front bumpers to the fenders and the side-view mirrors of the vehicle, provide the most common type of data that AVs generate. They are instrumental to the vehicle's perception system, providing valuable input to tasks such as object detection, road markings, and visual odometry.

Originally comprising simple dashcams, many modern vehicles now have a multitude of cameras, microphones, radar, lidar, and numerous other sensors. The equipment required to generate, handle, and store such data is vast and complex. Furthermore, these large overheads are necessary costs in operations such as mapping, path planning, and object detection, all of which are central to the functioning of AVs. An overview of the most common types of data which AVs generate include:

3. Privacy in Autonomous Vehicle Data Sharing

Numerous technical measures with privacy-preserving mechanisms have been proposed for autonomous vehicle operations, such as tracking, perception, and sensor fusion, routing, and data transmission. However, few methods have been considered in the challenging environment of complex third-party interactions, autonomous vehicle data sharing with passengers, and the dynamic operation of mixed fleets. When sharing decision authority or adjusting data visibility to passengers at data collection points, it is also important to understand the perceived privacy and trust boundary of vehicle users. Their visualization and affordances should be therefore considered in the development of privacy solutions.

Because complex sensors and algorithms are used in autonomous vehicles, data that is both identifiable and meaningful can be collected, linked, and subsequently shared with third parties. It is important to integrate privacy concerns into the development and deployment of autonomous vehicles to minimize potential invasion of user privacy, including the risks of personal security, profiling, and reputational damage. Nonetheless, unlike traditional vehicles in which a perceived degree of control of data sharing can be achieved through decisions made by the vehicle owners, privacy should be considered with more nuance in autonomous vehicles to ensure that user control and the user experience, as well as the performance of the vehicle and public safety, are all elevated.

3.1. Challenges and Concerns

So, it is essential to develop trust among all data sharing stakeholder groups which include existing big data owners, transit agencies, autonomous vehicle manufacturers, and policymakers. Addressing these concerns maintains the opportunity for public-private partnerships while advancing the benefits of the NHTS deployment. The participation from all stakeholders could lead to best practices in managing public trust. It would serve as a tool for federal, state, and local policymakers, service providers, technology innovators, and advocates to engage the public early and receive input on transportation data-related policies as the deployment comes closer. The best practices could promote widespread and open research on innovative and sustainable data governance policies to enhance travel data analysis and modeling.

While data sharing across a variety of scenarios would maximize benefits from a transportation system, it introduces challenges and concerns. This is especially the case for scenarios in which a large amount of data (including private data) is generated, and the data controller and the data consumer have different stakeholders. In such scenarios, when privacy controls on the sharing process are lacking or are not well-designed, the process can arouse public concerns and deter participation. Participants may fear that their privacy will not be sufficiently protected in the planned data sharing. If the public does not trust the data sharing scenario provisions, they might attempt to influence the data sharing process or may even sabotage it in response to what they feel are perceived or real privacy threats. This lack of privacy control will deter potential participants who might have made vast contributions to the public collective intelligence that would result.

3.2. Current Approaches to Privacy Controls

Linked work, related to review work, and relevant to car settings play with consent design. This paper compares some basic consent interfaces, ultimately finding no silver bullet. When some practitioners in car technologies set out to address data practices like apps that collect more data than they require, a first attempt to allow the user to refuse to give up location-based data in Mobile-Based Crash Reporting Systems met with failure. As understood by experts in complex systems, conflict—in this case, between accepting imposed monitoring and fears about potential traces of surveillance and ethics—poses a problem. California's new Consumer Privacy Act seeks to address the ethical problems California faces with notice and choice, but researchers, led by one of the leading experts on notice and choice, has pointed out that the language of individual control tends to shift society-level issues onto individuals. Solutions are ethically and politically engaged, such as to define more normative taxonomies of decisions that organizations need to document and treat data as a public good. This brings us back to the questions of more transparency and fairness that we explore in the rest of this paper. Its boundaries suggest that the EU's General Data Protection Regulation's legal term legitimization failure may guard against enterprises diverting decisions into individual terms in order to retain the choice to impose surveillance.

We now review current approaches to privacy control in car technology and related domains. Evidence that users lack effective transparency into or control of car sensor data traveling beyond the vehicle underscores the relevance of the work in this paper and echoes long-standing concerns about Electronic Control Units' location-based data collection. California's new Consumer Privacy Law aims to address these concerns, but giving people notice and choice about sharing through Privacy Settings may create a fragmented web of regulation that leaves people without effective control over their data and disproportionately firewall some firms from competition under the law. Similarly, past efforts to enable users to refuse to participate in large online social networks, install their own TOR servers, or sideload iOS apps have met with great difficulty because they require beaten paths to be consciously abandoned by multiple people.

4. Human-Centered Design Principles

By using the design principles provided by Batya Friedman and Helen Nissenbaum, we ensured that the design involved the consideration of ethical and political values and interests: human dignity, privacy, autonomy (including freedom of thought and agency), respect, and democratic participation. These design principles, including respect - curbing user autonomy; accompaniment - following the user's initiatory impulses because the controller is in charge of the journey; authority - reflecting the full, individualized ethical and value responsibilities of the controller; charity - protecting the user from harm or danger, and enabling the user to control the consequences of the journey; and responsibility - ensuring the vehicle is accountable for the consequences, focused on the assertion of moral responsibility for intelligent autonomous vehicle acts demonstrated how the technology design should reasonably reflect our evolving standards of ethical conduct. The involvement of the user was identified as central in separating responsible and knowingly bad actions. The design also needed to reflect the fact that human decision-making may be influenced by contextual and situational factors that rely on the involvement of users.

Integrating human needs and considerations into the development, deployment, and evaluation of technology is important to foster an environment of trust in the technology. As researchers, we can do so by paying attention to the needs, values, capabilities, and context of technology users. In an effort to align the proposed system design with the values embedded in the General Data Protection Regulation, a human-centered approach was taken in the design, where the conceptual privacy control system and its operation for user-notification, response, and decision-aid capabilities were designed for an autonomous vehicle data-sharing environment.

4.1. User Empowerment and Control

A user-centered approach must allow for personal privacy preferences and afford users an actively measured "direct control" (e.g., opt-in/opt-out) and "indirect control" over their data use in ways that intelligently align with and respect their contextual integrity expectations by helping them make decisions based on appropriate contextual cues as well. We advocate that the level of designing for user engagement empowerment and control should be more at the empowerment end, meaning that AV should encourage diverse behavior that reflects how users wish to engage with privacy settings, so long as it is thoughtful, appropriate, and consistent with their goals and moral principles. Privacy settings should not be overly complex, despite the potential risks privacy interface overload in driving. This means a careful consideration of how to provide layers of privacy designs into a user interface for privacy controls. This interface design requires balancing the trade-off between user comprehension and the extent of direct control since users often have limited understanding of how a system uses data even when the system provides simple consent mechanisms.

When it comes to real-time sharing of data in AVs, it is important that drivers and passengers have a user interface that allows them to customize and select which data they want shared with the purpose of contributing to the benefit of the common good. Against this backdrop, we propose a third dimension of trustedness based on "user empowerment and control" of data sharing to those who are riding in the AV. The significance of the user-centered approach in privacy control is based on the notion of informed privacy management by users. This approach recognizes that privacy-control mechanisms cannot be a one-size-fits-all solution because different users have different understandings of and privacy concerns about autonomous vehicle-related data that is liable to be collected.

4.2. Transparency and Trust

Transparency also serves a facilitative role with respect to user control of personal information. Service users expect continued easy access to interacting with technology; maintaining a level of transparency that increases trustworthiness becomes an important component of this expectation. Even more basic mechanisms of communicating trustworthiness, such as making electronic devices operate so-called "asocially," can increase or decrease trust and influence acceptability and real-world use. Establishing the level and kind of transparency needed, however, requires evaluation through empirical research, and emphasizing the importance of usability to privacy, security, and ethical safeguards can help ensure that near-term automation realities do not compromise far-reaching technological possibilities.

Transparency is a critical factor contributing to trust in technologies, particularly those with significant social and ethical impacts. Increasing transparency in autonomous vehicle technology has important societal implications, including its acceptance and use. Regulatory emphasis on transparency has been increasing, particularly in light of the challenges raised by liability, risk, and safety-critical situations involving these technologies. The 2016 Federal Automated Vehicles Policy was exemplary in its inclusion of recommendations about transparency throughout vehicle testing and deployment. The EU General Data Protection Regulation includes transparency as a foundational principle in its protection objectives.

5. Methodologies for Designing Privacy Controls

We focus on autonomous vehicles and the challenges that designers face when implementing end-to-end comprehensive privacy controls for the variety of information that is used to operate the vehicles, to help provide their intended function, and to provide cooperative intelligent decision-making capabilities. To our knowledge, control of vehicle information to accommodate the need for occupants' privacy has been relatively unexplored. We discuss the multidimensional nature of the challenges and provide a preliminary exposition of human-centered privacy control systems that combines the scale and scope of the legal and regulatory options available to designers, genuineness, and realism of various methodological approaches, humanizing the data economy. An important fact is that community and individual control become meaningful only at a certain systematic strength. This is at a broad juncture, the main idea to combine legal and law-based angles in search for more adequate methodologies and solutions. We posit that transparency and clarity of available data privacy control options about the risks should lie in the focal point of information flow, system decision-trust evolution. The paper seeks the roots, mode, and format to use data in safe design of autonomous transportation systems, including cybersecurity and occupant privacy.

Control principles to ensure the stability and robustness of autonomous vehicle systems need to be developed. As important it is to mitigate such human safety risks, and thus provide a higher, homespun level of trust in the safe management behavior of the vehicle and the entire infrastructure.

Introduction Designing effective and privacy-protecting systems and solutions for complex and intricate information flow paths in autonomous vehicles and smart cities necessitates human-centered methodologies. In this article, we introduce and decompose a comprehensive framework of the vehicle-information lifecycle. We posit that the context and role of vehicles in a wide variety of scenarios is diverse and unique, and that the right to privacy in one's travel and occupants of connected and intelligent vehicles is a crucial concern. We synthesize design implications to provide flexible privacy controls throughout dynamic vehicle-information frameworks. Transformational technologies for vehicles are exciting and have the potential to improve and transform personal and community mobility. However, the bi-directional flow of information between the advanced vehicle technologies and the communication and infrastructure, especially privacy and cybersecurity risks.

5.1. User Research and Needs Assessment

Privacy has been and is a growing concern among users of technologies such as mobile devices, smart homes, and smart cars. A large body of user studies demonstrates that users often worry about the data collected about them, yet they lack adequate control over what data is being collected and with whom it is being shared. If privacy controls that empower users to define their own privacy boundaries and share their data selectively become more available, users would be willing to share more types of data with more people in more contexts, including cases where the data is aggregated and less personally identifiable.

In order to facilitate the deployment of the proposed privacy controls in AV systems, it is critical to better understand the privacy concerns and needs of its end users. In particular, what specific data do various stakeholders such as drivers, passengers, operators, and third-party service providers prefer to keep private? To answer this, we performed several focus groups and interviews to investigate the privacy concerns of these stakeholders. After this initial need assessment, we furthered into identifying design requirements for privacy control mechanisms that facilitate data sharing based on these user-provided privacy requirements.

5.2. Prototyping and Testing

Our early prototype consisted of a tablet supporting a survey application connected to a low-power embedded sensor processor reading OBD data and vehicle sensor data. Thirteen artificial personas were generated with simulated profiles, and we used a monitor to visually represent three matches using icons. A different privacy control was associated with each avatar, mixed gender, and age. The target vehicle was located in a testing facility with standard A1-size posts and gates forming a route providing official road signage, vegetation, and overpasses, resembling real traffic conditions. To present realistic driving conditions, further participant exposure has been done in the evening, providing different ambient lighting and reduced daylight through spotlights. A participant first entered the vehicle and received a basic explanation of the concept, the applied technology, and the nature of their tasks.

Once concepts for the privacy controls were designed, we combined mock PICs, simulated data, and an autonomous vehicle application in order to prototype them. Our prototype was a demonstration with real-time interaction in a vehicle at a speed of 10 km/h. This helped us to assess the practicality of the privacy controls and identify possible adjustments, for example, how it would work in different driving conditions and for different age groups. Furthermore, it allowed for a real-time experience that cannot be achieved in the form of a video. After prototyping and making necessary adjustments, we conducted a laboratory evaluation in which our modified prototype has been shared with 37 participants using a wizard-of-oz (WoZ) setup. Based on the feedback from the participants, the prototype has been further improved. These stages for prototyping, evaluation, and iteration were found important as privacy controls have to be both intuitive and unobtrusive while still effective.

6. Case Studies

To explore how to differently design for the privacy of connected and autonomous vehicles from traditional understanding, we present a network of stakeholders from the domains of disability studies, ethics, critical theory, and university campus services, of course also accompanied by technology insights and concerns through inclusive conversation prompts to describe and define new forms of privacy risk scenarios, categorized according to their dimensions that are collectively used to assess situations to develop finer privacy controls that are fundamental, efficient, and effective. With redacted, three case studies here showcase outcomes of the variant dimensioned risks, with deeper insights and a resultant feasibility to relate and establish guidelines to maintain trust through specific, general, or global privacy considerations to maintain pre-established control through the social privacy processes. We note how user personas refine the dialogues and simulations.

Practitioners/vendors come up with privacy defaults. The data and analytics models have limited or restricted access to data, for example through process-level or access restrictions, where private data can only be shared with specific, traceable users of legitimate use. These maintenance and reporting controls shift burdens from the end-users to responsible data custodians.

In this section, we present two case studies for which data sharing in level 4 autonomous vehicles might have privacy implications. The goal of these case studies is to probe and reflect the relationship between entrenching privacy controls in the data sharing processes of the vehicles' SAE-J3131 Emergency Services Interoperability Framework (ESIF) and human-centric goals of how users would perceive privacy about sharing in contexts that are different from established ones like web applications. The two cases serve to expand the significance of sharing and establish more complex, social privacy patterns and their implications on design. By involving end-users and deriving their perspectives, the reasoning frames including established standards get an augmented validation in use that drives wider impacts through privacy and trust that in turn adjust and effect impacts of emerging technologies and services.

6.1. Successful Implementations of Privacy Controls

Apple provides a device built into the automobile platform to allow sequential vehicle monitoring data to be removed from an Apple compatible iPhone. A user must open up an iPhone security setup, press privacy, and then switch a toggle from on to off. Ford's automation iOS app provides a rather diverse interface allowing vehicle location and auto fitness monitoring to be accessed. A user must tap the automobile app lip to display much of the car app, press the "i" logo in the top corner of the app, navigate to the "Connected services and settings" pane, then select "edit" in the "Vehicle Permissions" segment of the window. Apple, the automaker, Ford, and the software company, Telenav, each released automotive dashboards or automobile applications between 2016 and 2019.

Successful implementations of privacy controls that facilitate control, notice, and preference, as described in Table 1. The devices studied within this project shared driving and location data with car manufacturers or by proxy, third parties. Apple, the automaker, Ford, and the software company, Telenav, each released automobile dashboards or automobile applications between 2016 and 2019. Importantly, the design characteristics of the privacy tools in use will influence the potential use of those devices since a participant might assess these tools through their information affordances, contrary to experts. These evaluation techniques are discussed in the Pilot Study Methodology section below.

7. Ethical Considerations

In summary: Frequently exchanging, reviewing, and revising design studies with stakeholders ensures privacy and business model compromises are proactively identified, understood, minimized, justifiable, and potentially revisited by design decision-makers. Integrating diverse stakeholder insights reduces polarized mutually regrettable privacy loss or business growth through privacy conflict resolution. This can be achieved, using a contemporary systematic lens, over a generation of engineering research/problems. It is the role of policymakers and organizations to listen to the essence of such deliberative democracy trait balanced 'privacy a configuration phase 0 strategy crafted by stakeholders" boomerang hollow factorial workshop outcomes back into data sharing regulation and tool design updates, prescribing analyses with new demand for business success, fairness, and accountability signals.

Gained clarity. We aspire to promote stimulating, balanced dialogue amongst participants with varying interests, to mutual benefit erection of strawmen to acknowledge and mitigate outcomes improved ML privacy question comprehension. Ethical considerations a) privacy remit expansion to consider aspects including threat and consent to external third parties, systematic privacy rights violations (violent actors and stigmatizations), and whether data sharing concerns have relevance beyond privacy jurisdictions; b) acknowledging data sharing disagrees about the need for third-party privacy and benefit infringement justification: were disparate group concerns co-located in physical design space? This EF was revised to clarify our Privacy Reflections question. Strong connections were strongly influenced by ethical trade-offs e.g. individuals respect an opt-in privacy system default setting; businesses valued wide availability, but not at the expense of financial verification consequences. For all EFS, privacy and privacy right connections with provenance and inference risks fell strongly at the intersection of subsections, inspiring the quadrinity representation in Fig. 2 Why Human-Machine Co-Design Matters.

Ethical considerations: Were privacy and data security challenges met and goals achieved for the stakeholders with whom we co-designed? Did we address compromises and outright ethical dilemmas, requiring trade-offs within and between co-design workshop participants' goals and constraints? Privacy and data security fundamental questions permeated each workshop. The underpinning problem (explaining why stakeholders might prefer different sharing granularity preferences) is because spatial-temporal-semantical data is valuable to all stakeholders. Before data are shared and used by third parties, human participants need to feel in control. Due to the nature of data and derived inferences drawing inferences from passive collection of AVE data, real stakes are involved as with future privacy, business models, and consequences. Participants had a strong preference for data. Data aggregation and inference risks elicit users to withhold sensitive information from, or not use, services that benefit society. Participants also want to grant autonomous vehicle manufacturers data sharing rights, aligned with business innovation and development imperatives. These priorities create dilemmas. For example, does providing no AVE data sharing controls violate privacy ethics, and no manufacturer data access needs to access potential limitations inequalities consequence; deprivileging the world's wealthiest consumers frustrate or threaten business sustainability? Did we address these (and similar) ethical questions: outcomes improved ML privacy tool design.

7.1. Informed Consent

Traditional means of expression provide a structural guideline of content requirements to achieve a legally enforceable agreement. The elements encompass that consent must be informed, unambiguous, and given either by a clear affirmative act or by a statement or conduct which clearly indicates, in this context, the data subject's agreement. As such, the General Data Protection Regulation (GDPR) extends the content requirements to include the right to withdraw consent and the right to be informed in a concise, transparent, intelligible, and easily accessible form, using clear and plain language, with the right to access an underlying controller legal personality. To accomplish alignment with user preferences and trust, particularly transparency and user comprehension, encourage interaction during the first point of contact. This study emphasizes how additional guidance can be communicated to influence a willing user's agreement while providing convenient accessibility.

Although informed consent has attracted criticism in data protection circles, two scholars note that consent exhibits a flexible and dynamic nature across different contexts. We adopt a more nuanced understanding of what it means for an entity to provide its meaningful agreement to a transactional practice by aligning its goals and objectives with its preferences, supporting active user involvement in control design decisions. Previous work showcases the challenges in seeking autonomous vehicle owner consent to gather and share data stemming from the fact that people may not fully understand how data sharing works, may not appreciate the trade-offs during consent, or may not be aware of their rights and obligations. Consumers, in general, tend to tick terms and conditions without reading them, and this is likely to happen with respect to data sharing agreements for autonomous vehicles as well.

7.2. Data Ownership and Use

Consider a scenario where a vehicle has entered an agreement with a manufacturer de facto stating that the manufacturer and not the vehicle owner controls the data produced by the vehicle. This scenario becomes far more interesting if one considers data exchange between two companies in the same commercial sector, say both involved in ride-sharing, either from a platform level and collecting data from a variety of rides and cars, or from an individual car level with a partnership agreement. In both cases, players have an interest in keeping the partnership data exchange open and might be willing to offer monetary compensation to both companies' players. This added (commercial) value might easily alter the perceptions of vehicle owners and customers, with a high perceived cost of not allowing the data exchange if it is both entirely harmless and providing services that are in the user's best interest.

One of the hotly debated issues around the concept of data privacy's design is the question of who actually "owns" the data. Various data privacy regulations, such as the "personally identifiable information" concept now widely enforced in the US, rely on attributes of the data itself to determine who can control the data's use. However, within the particular domain of data from a set of vehicles and their drivers, it may not be clear who actually is the data owner. If a vehicle is owned by an individual, and that individual is covered by the data privacy laws of their personal state or nation, then that individual is the data owner. If the vehicle is owned by a rental car agency, or belongs to a ride-sharing service, things become far less clear because the actors who provide the car for use by the individuals gain value, perhaps substantial value, from the use of that data, and thus might argue that they are the data owner.

8. Future Directions and Recommendations

Future research will expand upon these initial studies by examining the use of the PVCS by individuals who do not have experience with vehicles and thus do not have the same personal concerns about and understanding of autonomous vehicle data issues. Such a study would include one designed to determine how different demographics (for example, age, insurance ownership, business usage, etc.) experience and understand the impacts of widespread autonomous vehicle data sharing. It would then observe the process of groups designing their own configurations, just to see what people think might be important – in the absence of having to set, for themselves, a level of data that they are comfortable sharing. It would thus form a broader community discussion. Additionally, in all of these, we would like to measure tool use over six months to see if and how the tools get used over a longer timeframe.

Drawing on the results of the studies, we have connected the tools to foundational privacy literature, proposed a conceptual model of systems and interaction design of autonomous vehicle data privacy controls, and provided a set of overall considerations for responsible design in co-designing such tools. Based on these findings, we deliver several recommendations for those responsible for the design and development of future privacy control tools, designed to enable their responsible use and effectiveness in a range of autonomy and vehicle control scenarios. All of these contributions contribute to circling back to key researchers' calls, noting that scholars should develop a better understanding of the use of privacy settings.

In this paper, we have presented the results of two studies looking at the implications of autonomous vehicle data sharing and the development of two human-centered privacy control tools: PrivacyWrench and CruiseGuard. Both deliver the ability to manage who has access to autonomous vehicle data, but in different ways. The latter uses a touch screen strip functionality, while the former uses a knob and dial.

8.1. Technological Advancements

The concept of a fully autonomous vehicle (AV) is an exciting but often unattainable promise to many consumers. Though the stage for a fully autonomous vehicle is constantly advancing, there are some obstacles that still lie in the way of a fully self-sufficient AV. As Steve Adegbite writes, autonomous systems have clear vulnerabilities to tactics exploiting their dependence on sensor data for perception, orientation, and map making, and their reliance on sensor inputs from networks that pose cyber vulnerabilities. Any sensors used in support of a noisy-state estimator system, including Global Positioning System. To reach the level of autonomy for AVs, designers have to take into consideration these concerns without compromising the privacy of their passengers. In this chapter, we examine what technological advancements have to be made to reach this level of vehicle autonomy, comparison of different types of autonomy, concerns of vehicle autonomy, and what the stages of autonomy are. We then conclude with discussing how AVs can positively impact humanity and society.

8.2. Policy Implications

Connected vehicles and autonomous vehicles integrate increasingly sophisticated sensing and communication technologies. That includes technologies for vehicle maintenance, personal and organizational data management, and infotainment. It also includes technologies to interact with the environment and other vehicles, assist with process controls, and are essential elements of autonomous vehicles. By 2022, the Society of Automotive Engineers (SAE) Level 5, fully autonomous vehicle deployments are anticipated to enable vehicle passengers to travel without any need for direct interaction or oversight (e.g., the driving task and the responsibility are entirely transferred to the vehicle). Autonomous vehicle technologies rely on high-resolution sensors that report dynamic and static data on the status of the vehicle, the environment, the infrastructure, and the interactions among them.

Connected and autonomous vehicles generate massive amounts of data about individuals and their movements. There are strong market interests in that data and more generally in creating and sharing data about the state of the world. Automotive sensors differ in granularity, and vehicle-installed infotainment systems are connected almost ubiquitously to the internet. Rules and technologies to ensure that data-sharing choices are respected are thus essential. This chapter outlines how to address privacy and other control policy needs by balancing the conflicting interests of individuals, carmakers, and third-party data users. It concludes with reflections on permissible access to connected vehicle data in emergency situations.

9. Conclusion

We analyzed, designed, and implemented privacy control interfaces for AV data, which we believe will enable trust and development of responsible use of a data-intensive, promising, and contentious transportation revolution. Throughout this publication, we described the behaviors of the privacy functions in transportation—commingling data, moving data, making data, and storing data—limit what needs to be communicated with regulator and authority inquiries and what will be retained over time by vehicle owners. We described the privacy control interface options and metadata that existing location and photo answers offer and how they could be leveraged, general-purpose interface attributes that will help consumers understand inferred privacy loss or messages and query response policies that could be augmented for systems scheduled to be released in the future. Moreover, we described the experiences of Vector and Toyota in offering an open, published privacy control interface and attributes during real-world testing, focusing on data protrusions and user interventions in the self-drive process. Finally, we proposed three research questions for the privacy and management of metapolicy and V2X data control and privacy.

Autonomous vehicles have the potential to enable a vision of safe, efficient, and equitable transportation when drivers, city administrators, traffic engineers, and other stakeholders can take advantage of the new types of data and services that AVs could provide. Efficient use of AVs is strong real-world evidence of their value to society. However, real-world deployment of AVs has raised concerns among citizens and regulators because autonomous vehicles will generate and process information about their environment, passengers, and operation. Research has started to investigate how to communicate privacy-protecting operational details about vehicles, blending current concerns, the functionality of systems proposed in this context, and the privacy experiences of people who use these types of systems.

9.1. Key Findings and Contributions

Because our study is formative, the probability sampling unit of the population was not necessary in order to study whether or how vehicle owners believe that their data should be controlled, nor should accelerating change of industry that is regulated without considering the opinions of those whose norms and values are infringed when they will travel in an AV, own an AV, or release AVs onto the roads be delayed. Nonetheless, our research extends understanding by informing the future types of controls that might enable better management and induce trust for participation.

This exploratory study introduces the potential privacy threats generated from autonomous vehicles. Our results suggest that the study participants held consistent privacy concerns related to location tracking, secondary uses of data access, and joint exposure of private data. We contribute by articulating attributes for the design of privacy controls that together reflect the expectations and preferences of vehicle owners, riders, and manufacturers. We bridge a gap by proposing that vehicle privacy controls consider a balance of features that can be easily communicated without overcomplicating the perception of management.

9.2. Limitations and Areas for Future Research

Another area for further research concerns the value of various different types of features that vehicle owners would like to quantify related to their vehicle or user-generated content-based data sharing. How valuable are different sets of vehicle (and driver) operation user-generated content or IoT data elements? Presumably not all elements cost the same to collect or monetize (or to 'fix,' for example, in the case where reverse engineering to create privacy is the fix). We hope a rich vein of future research across multiple academic disciplines will concern niches within the sharing economy, such as whether a 'bang for the buck' - possibly reflecting legal and design consequences – for various types of vehicle user-generated content is measurable. Data on how users respond to privacy controls designed around different sets of data features to share or not to share is scarce.

In designing pieces of this larger puzzle, we recognize an important limitation of our study; namely, the ethical issue of the fine level of granularity of the data on how cars drive that we present to participants. Indeed, under different assumptions, our data may form the core of an entirely different privacy discussion on data sharing beyond the life cycle of the individual vehicle. From shared mobility services to third-party fleet management, the data used comes from potentially many different owners of the vehicles serviced by the data-sharing platform. There could be an ethical issue in presenting more than summary data regarding how any specific given journey takes place.

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