Pool More, Drive Less: An In-Depth Qualitative Investigation of Barriers and Motivators of Ride-Pooling in Autonomous Vehicles

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ABSTRACT

Ride-pooling (RP) in autonomous vehicles (AVs) has the potential to combine the sustainability of public transport with the comfort of a private car. In our study we investigated consumers' acceptance of RP in AVs through in-depth qualitative interviews, identifying relevant barriers and motivators of using this new mobility service.

INTRODUCTION

Technological developments – digitization, automation, and electrification – allow for radical changes in the mobility market. Especially, the advancement of autonomous vehicles (AVs) pushes this wave of innovation. AVs are expected to make traffic flow more efficiently, especially on motorways. However, recent simulation results show that unregulated use of AV can lead to an increase in travel demand and to more congestion (Hörl et al., 2019). Ride-pooling combined with AV technology has the potential to mitigate these problems by combining the advantages of public transport (higher vehicle occupancy) and private vehicles (direct trips). Further, ride-pooling allows for substantial accessibility gains, especially in areas and during times of the day for which conventional public transport services cannot be efficiently operated.

A number of current studies is related to the acceptance of ride-pooling in AVs: What risks do passengers associate with ride-pooling in AVs? What are expected benefits? Answers to these questions are required to produce credible estimates of the potential of ride-pooling and to advance our understanding on how to promote pooling in AVs. In addition, results may inform transportation service providers, policymakers, AV designers, and other stakeholders about behavioral and service-design factors that will impact the uptake of pooled AVs.

Ride-pooling

Ride-pooling (RP) describes pooled on-demand mobility where travelers may share a ride with other passengers during the whole or a certain part of the trip. The service is provided by professional operators and thus differs from carpooling, which is a service where private people offer a shared ride (Sonneberg et al., 2019). The pick-up and drop-off of rides can happen at existing public transport stops, virtual stop points or at a specific address (door-to-door). This depends mostly on the service operator and the geography where the mobility service is offered. So far, most RP services, i.e., the usage of vehicles with four to eight seats for shared taxi services, have only been tested in pilots with conventional vehicles and with professional drivers. More efforts are needed to achieve a large-scale implementation. MOIA for instance, a RP transport service in Hamburg, Germany operated a fleet of 250 vehicles in 2019 and served on average about 6 000 trips per day. With an average occupancy rate of 1.33, the service served only about 0.11% of all trips and remained a niche product (MOIA, 2021). This example shows that the potential of RP is still very high and can further be exploited.

Ride-pooling in Automated Vehicles

Automated vehicles (AVs) in their most advanced stage permit fully automated driving and aim at being more efficient and safer than driver-operated vehicles, and even increase resource utilization by enabling new car sharing models (Thrun, 2010). In the case of ride-pooling in AVs a driver becomes obsolete and the space in the vehicle can be used otherwise. Mobility on-demand, especially RP in AVs, could provide the best option for an inexpensive service which will contribute for very much needed sustainable solutions (Kramers et al., 2013; Martinez & Viegas, 2017) as well as for a facilitation of multimodality (Krueger et al., 2016).

Previous Insights into Acceptance of AVs and RP

In the past few years, several studies have addressed the psychological factors influencing behavior related to riding AVs such as perceptions of safety and technology adoption (e.g., Bansal & Kockelman, 2018; Zmud et al., 2017).

Concerning RP research has addressed this very specific mobility service as described above in combination with psychological factors (de Ruijter et al., 2021; König et al., 2018; König & Grippenkoven, 2019). Additionally, insights about carpooling and ridesharing can shed light on determinants that can be related to RP. Studies have shown that barriers and motivators might exist regarding the trip purpose (i.e., long or short distances; leisure or work; etc.), the usage of an app or other tools while planning (i.e., usability and data privacy), personal and social attitudes (i.e., norms; socializing; flexibility; etc.), travel and waiting time, and number of passengers (see e.g., Adelé & Dionisio, 2020; Alonso-González et al., 2020; Hörl et al., 2020; Kang et al., 2021; König & Grippenkoven, 2019).

More recently, studies focusing on individuals' attitudes found several factors that influence behavior of using RP in AVs, such as accessibility, technology improvements, cost-saving, information, improving the built environment, reliability, adoption of technology, security (Etminani-Ghasrodashti et al., 2021), trust in the AV (Hörl et al., 2019; Nordhoff et al., 2020), comfort, time, perceived costs (Stoiber et al., 2019), and anxiety in social situations (Dolins et al., 2021).

Development of these technologies are fast paced. Likewise, consumer's knowledge, experiences and preferences with regards to using AVs and RP are shaped by these current developments and need to be tracked and continuously investigated to understand and better predict consumers attitudes and behavior. Our study contributes to filling the gap of current determinants influencing the intention to use RP in AVs. Further, an in-depth analysis of the barriers and motivators related to RP in AVs can provide a deeper and more differentiated understanding of the determinants to use these services.

METHODS

Research Approach

To investigate barriers and motivators related to RP in AVs, we adopted a qualitative exploratory approach. Semi-structured qualitative interviews allow for exploratory data collection and permit an in-depth investigation of factors such as attitudes and behavioral tendencies (Brinkmann, 2014). Furthermore, the time perspective (talking about hypothetical scenarios in the future, such as using RP in AVs) is a challenge that can be overcome by applying specific interview methods, such as the narrative approach (Sools, 2020).

Sample and data collection

We conducted 19 semi-structured qualitative interviews. Participants were people living in the German-speaking part of Switzerland who were either mostly public transport user (n=9), both public transport and private car user (n=3), or mostly private car user (n=7). Participants were balanced in terms of gender (male, n= 9; female, n=10) and aged between 21 and 61 years. The interviewees received a monetary incentive for their participation.

Each interview took between 45-60 minutes and was conducted remote via Zoom. The interviews were conducted by trained interviewers following a pre-tested semi-structured interview-guideline. All the interviews were recorded and transcribed.

Analysis:

The transcribed interviews were analyzed using the software MAXQDA based on the procedures of structured content analysis (Nielsen et al., 2015; Radke et al., 2011). In a first step, interview-transcripts were coded by two independent coders along the main categories based on the findings from the literature research.

In a second step, subcategories were identified and classified as either a barrier, a motivator or a neutral factor. This resulted in a two-level structure of the coding system: (1) main categories (deductive coding), (2) subcategories that are classified as either a barrier, a neutral factor, or a motivator (inductive coding).

RESULTS

Relevant determinants were categorized into 21 main categories (Table A: Appendix). The results of the present study replicate results from previous studies, confirming the relevance of several determinants such as safety, security, availability, or privacy concerns etc.

Analysis based on the subcategories revealed a variety of barriers and motivators that are relevant to explain the intention to use RP in AVs. Frequently mentioned determinants are found in the categories: safety, time, availability, flexibility of the offer, environment, socializing, and reliability. The determinants *security* and *reliability* are discussed in further detail below. Table 1 lists the valence (i.e., barriers and motivators) of the identified subcategories for the two determinants.

Table 1. Subcategories and valence of safety and reliability

Determinant	**Barriers (B)**	**n (B)**	**Motivators (M)**	**n (M)**
Safety	Feelings of insecurity at the beginning	14	Trust due to growing familiarity	18
	Distrust in technical functionalities		Trust in technical functionalities	
	Difficulties at handing over control to a machine		Safety standards: Trust and information	
	General fear, fear of accidents and/or technical issues		Less susceptible to human errors	
	Helplessness in case of technical issues		Presence of driver or other passengers	
	Feelings of uneasiness			
	Safety issues for other road users			
	Concerns about unforeseen situations			
	Guilt in case of accident			
Reliability	Unreliable	10	Reliable (2)	9
	Less reliable than public transport		Suitable for journeys without fixed appointments (2)	
	Unpredictability of vehicles available		On-time when planning and enough information available	

Notes: B = Barriers; M = Motivators; n = Number of interviewees, stating arguments in this category.

Safety

Safety is defined as feeling safe regarding technology and infrastructure. The barriers related to safety include feelings such as fear of accidents and technical issues, helplessness in case something happens, general uneasiness, and guilt in case of an accident (see Table 1). Unforeseen situations as well as concerns about other road users seem also to be an issue. The former can be related to extreme weather situations *("I am still critical how such technology [works] with black ice and slush. And how the sensors work in bad weather and bad conditions."*) or unforeseen situations *("It would be dangerous, if the AV would not be able to detect and recognize animals or people […] and put, any animal or anyone in danger, then I*

would not use it in any case.") The same applies to the control that passengers need to give up when riding in AVs .

When it comes to technical functionalities, we see controversy. On the one hand, some participants experienced distrust related to technical functionalities (*"The car thinks for you and that is just dangerous."*). On the other hand, participants reported trust in technical functionalities. Trust in safety standards is generally very high, and for some, information about safety standards builds trust. AVs are often perceived as less susceptible to human errors and thus safer than driver-operated vehicles *("Nevertheless, technology is more reliable than people. I am convinced of this."*). A general sense of unfamiliarity at the beginning is common due to this new mode of transport. Also, riding with others evokes a positive feeling of safety *("When something happens, I am not alone. Actually, it's exactly the same. But you're not alone in the boat. You are kind of together and it changes the feeling. It gives more security."*).

Reliability

Reliability refers mainly to issues related to punctuality and predictability. A large share of participants perceives RP in AVs as being unreliable (*"In terms of planning, the problem is that it doesn't always leave reliably at [a specific time]"; "For example, if I know I have to be in town on time at a certain time, I don't know if that would be the service for me."*). Only a few perceive RP in AVs a reliable service (*"Yes, I think that is very punctual and you can rely on it"*). For few participants public transportation is more reliable than RP in AVs (*"With the bus, I know exactly when it leaves. I don't have to do anything, it's there. It has a fixed, predictable schedule."*) and one participant argued that the unpredictability about the availability of vehicles hinder him or her to choose the service.

GENERAL DISCUSSION

Due to its potential to solve transportation issues such as pollution or congestions, RP in AVs is a promising mobility service. Understanding consumers' preferences is of fundamental importance when it comes to accelerating the adoption of innovations in the marketplace. Furthermore, it is very important to be able to differentiate consumers' (changing) attitudes to keep pace with the fast-developing industry. In our in-depth qualitative investigation, we could verify 21 different determinants that influence the use of RP in AVs. We were able to replicate the findings regarding the mere determinants already assessed in prior research (Adelé & Dionisio, 2020; Alonso-González, van Oort, et al., 2020; Dolins et al., 2021; Etminani-Ghasrodashti et al., 2021; Hörl et al., 2020; Kang et al., 2021; König & Grippenkoven, 2019; Nordhoff et al., 2020; Stoiber et al., 2019). However, instead of categorizing the determinants into barriers or motivators, we went a level deeper and were able to gain a more differentiated understanding for each of the 21 determinants by identifying for each determinant three subcategories: barriers, neutral arguments, and motivators.

We described two determinants: *security and reliability* in more detail. The in-depth analysis from the qualitative interviews allowed us a more differentiated view of the factors driving the

intention to use RP in AVs and uncovered several controversial motivators and barriers. For instance, regarding safety, some participants reported to feel secure and to trust the technical functionalities of an AV, whereas the opposite was true for others. This shows a much more differentiated process of assessing the own preferences and suggests that to identify consumers' preferences, we need to dive more deeply into the argumentation of costumers.

A similar picture was found for reliability. From our in-depth interviews we can conclude that people are concerned with issues such as punctuality and predictability. There is a tendency to perceive RP in AVs as being unreliable. However, this issue becomes less relevant, if RP in AVs is used for non-time-sensitive trips such as leisure trips, where arriving at a specific time is not very important. Another argument that can be seen as a motivator for RP in AV is when the trip can be planned well in advance.

The discussed examples show that determinants can be used in the argumentative process and the individuals' construction of preferences as a barrier as well as a motivator. Thus, the preferences and resulting behavior do not merely depend on the general attitude towards RP in AVs but are very much related to specific situations and needs.

From these findings we can derive several recommendations that may inform policymakers, transportation planners and mobility providers likewise on how to design and promote RP in AV: E.g., providing reliable information about the trip (pick-up / drop-off) may reduce uncertainty and increase perceived reliability of mobility service. Or by offering test rides might increase familiarity with new mobility service and reduce insecurities.

Finally, we need to acknowledge the limitations associated with the present study. Likewise, to all research endeavors concerning innovative services that are not yet available to test and experience, findings are limited to the extent of participants' capabilities to foresee their future preferences. Also, the qualitative methodology was designed to uncover and explore barriers and motivators genuine to the acceptance of RP in AVs. Future research is needed to confirm the proposed relationships and different target groups using a quantitative approach.

Despite its limitations results of this study may inform transportation service providers, policymakers, AV designers, and other stakeholders about behavioral and service-design factors that will impact the uptake of pooled AVs.

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Appendix:

Table A: Main categories of determinants

1. Security
2. Interaction with the vehicle
3. Payment
4. Costs
5. Comfort (trip related)
6. Ownership
7. Safety
8. Social interactions
9. Social situation
10. Social norms/ expectations
11. Reliability
12. Flexibility
13. Information on app and planning
14. Availability
15. Time
16. Skills
17. Environmental attitudes
18. Privacy
19. Perceived control
20. Prior experience
21. Hedonic motivations