Human-Centered Design (HCD) for Shared Autonomous Vehicles Mobility in a Dynamic Society

200 hours of annual commuting time invested, not wasted

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Abstract. The increasing usage of ride-sharing and autonomous vehicles has presented a need for personalized mobility experiences. This research defines these needs through an investigation from passengers who have used or will use these services. User behaviors and pain-points were categorized through in-depth interviews and observations. The variety of responses and user pain points defined a need for a flexible solution that employ a safe, private, and comfortable experience during a shared ride. Four rounds of user testing were performed to understand user perception of a partitioned environment. From this, we discovered two importants insights: 1) both social and quiet individuals valued the option of having a private space during a shared ride, 2) users felt anxiety from fully segmented spaces due to the unknown of vehicle surroundings. We present a scaled functional prototype to demonstrate our human-centered design solution. It partially segments the shared space and provides the perception of security through personal physical space, privacy through asymmetrical viewing of adjacent passengers, and comfort through increasing the field of view of the passenger.

1 Introduction

Overcrowded cities and unpreventable traffic are the results of 1) considerable population growth of the last few decades [1] and 2) an increasing number of registered vehicles on the road [2]. People in the United States spend an average of 200 commuting hours per year and 6.9 billion driver hours are wasted due to traffic [2]. According to Texas A&M Transportation Institute (TTI) and Irinx, Inc., this issue yields a annual total cost of $160 billion from time lost and fuel consumption implied [3]. Avoiding wasted time on unnecessary activities is a main public concern, and there is a great opportunity to improve this problem by providing a flexible experience that caters to unique users' productivity needs.

The development of autonomous vehicle (AV) technology had opened new possibilities for future mobility solutions. It has created new ways of solving increasing traffic congetstion, with concepts such as "platooning" [4], and the existing commuting inefficiency [5]. Current automotive companies, ride-sharing companies, and academia are spending a considerable amount of time and resources in developing research and market testing on AV's role to address ground transportation challenges [6]. However, AVs are facing many challenges regarding safety, reliability, and technological unemployment; the transition to this technology will need to address these aspects before achieving a high market adoption.

During the last five years, the ride-sharing industry increased its market participation in transportation exponentially [7] and has revolutionized urban mobility, helping address the rising issues in congestion and commuting time [5]. This trend is projected to continue, especially with advances in AV leading to an expected switch from car ownership to ride-sharing services [8]. As the autonomous vehicle and ride-sharing platform converge within the next decade [9], with the growth of Waymo and Uber's Advanced Technologies Group (ATG), the ride-sharing passenger dynamics and experience within the vehicle become an increasing concern. For example, simple passenger matching is an exponentially difficult problem to tackle [10, 11], which is dependent on not only matching route compatibility, but also personal features such as gender, social status, and social interaction types.

Current methods already satisfy the most important features that end-users seek: getting from point A to B. This explains why high occupancy public transportation is still a viable business (i.e. buses, subway/train, crowded airplanes). Consumers do not mind sharing the physical space with other commuters,

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as long as the mode of transportation brings them to their destination. Additionally, micromobility has dented short-range transportation solutions, and their growth has overshadowed even Uber and Lyfts rapid growth back when they were still starting [12]. Moreover, there is still a preference for using personal vehicles because users also mobilize their personal items and require the comfort/accessibility of storage. Despite these alternatives, there is a gap in the market for flexible-customize and premium services.

The scope of this project is to address problems and user's needs under a scenario where the vast majority of the people will commute through autonomous ride-sharing vehicles, using Human Centered Design (HCD). By aiming to satisfy ride-sharing users, whose needs are currently not being completely met, the focus is on generating an easily implementable solution, with a target timeline of foreseeable future. We hope our approach will actively contribute to developing future mobility solutions directly by working with ride-hailing organizations in the future, such as Uber/Lyft, who are providing real-time solutions to address current needs in mobility [13], such as reduced traffic congestion, pollution, fuel consumption [14].

2 Methods and Approach

To explore new opportunities for the future of autonomous-rideshare vehicles, a human-centered design approach was utilized. Human-centered design is a creative approach to problem solving where a product is designed through strong empathy with the end user [15]. With the increasing usage of new vehicle types, autonomous vehicles, new users, and ride-share users, a human-centered approach will be utilized to find new opportunities to address newly unveiled user needs. We employ HCD methodology to this issue by conducting personal in-depth interviews with various users, find correlations within these interviews, define needs for these correlations, generate concepts to address these needs, develop prototypes, test, and iterate.

2.1 In-depth Interviews

In-depth user interviews were first conducted to understand what were the main pain points of users while riding a vehicle and their perceptions on ride-share and autonomous vehicle technologies. Twenty interviews were conducted, interacting with users from different backgrounds and diverse commuting preferences to identify the main mobility problems that each of them had experienced. The interview protocol was based on 19 questions within six different categories: Pre-survey (4), Background (5), Ride-share (3), Sensing (1), Autonomous Vehicles (3) and Conclusion (3). The outcomes of the interviews were classified by identifying core users needs through quotes. Each of the quotes represented a specific user need and was then clustered into labeled groups, allowing analysis of each interpretation collectively. They were assigned to seven categories: Safety, Privacy, Entertainment, Comfort, Convenience, Hygiene and User's Control.

Quotes and user's needs corresponding to these classes were grouped and analyzed through 2 x 2 matrix analysis. The main objective of this technique was to identify gaps in a two-dimensional graph which labels all users interviewed under specific criteria. Figure 1 shows the correlates passengers' willingness to socialize in a ride and their preference between using a personal vehicle and sharing the ride. The main conclusions were: 1) people that are more likely to prefer a quiet ride prefer using a personal vehicle rather than a ride-sharing service, 2) people that mainly use ride-sharing services for commuting tend to be more talkative. Therefore, considering that an increase in ride-sharing commuting is expected with the development of AVs [8], there is a gap that current ride-sharing services are not addressing; giving more quiet people more privacy in their ride while pooling with another passenger. This is one of the main opportunities obtained from the insights of this research and was considered in the development of the proposed final solution.

The second 2 x 2 matrix analysis in Figure 2 constructed compared user's trust in AV technology with the amount of time they spend weekly inside of a car for commuting. The analysis found that people that spend more time inside of a car tend to be more confident about AVs. One possible explanation may be that people who stay longer on the road experience more pain points related to their commuting experience. Taking this into account, the solution will try to fit the needs of short distance commuters with different demographics and help improve their perception of autonomous vehicle safety.

The final analysis in Figure 3 was conducted to understand what passengers of different ages would like to do while commuting in an AV. It was found that people older than 25 years old preferred to rest while commuting, while those below 25 preferred to engage in other activities. Thus, the possible solution will need to give the users the flexibility to decide between a quiet and restful ride or a social experience with people looking for the same commuting experience.

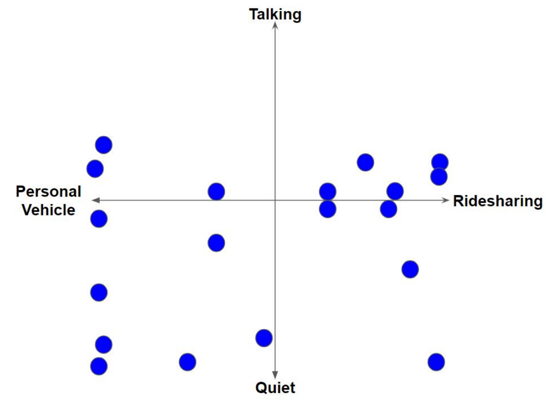

Fig. 1: 2x2 Analysis over peoples likeliness to talk and their ride preference. Trend shows passengers in ride-share or personal vehicles generally prefer to have their quiet time instead of conversing.

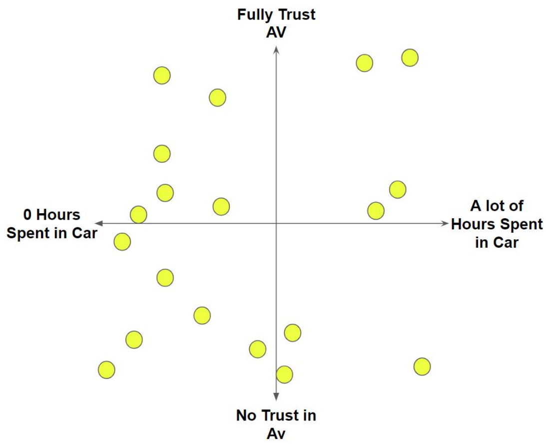

Fig. 2: 2x2 Analysis over peoples trust in AV and the amount of time that they usually spend weekly in a car. Trends show that people who spend many hours in side their car, whether they're stuck in traffic or have long commuting times, they do not distrust autonomous technology.

2.2 Concept Generation

User interviews and previous research with academic and industry experts provided the foundation for our concept generation activities. These experts covered the fields of mechanical and product design, interaction design, and User Experience (UX) design.

With the main user needs and current gaps in ride-sharing solutions identified, 72 concepts were developed and then clustered and filtered based on feasibility, ease of implementation, and ability to address the core user needs. The final three concepts obtained were the following:

1. Customized Vehicles: The idea of this concept was to create a flexible mobility service according to user's preferences. By delivering a vehicle with a different configuration representing a particular concept, users would be able to enjoy a variety of commuting experiences according to their mood and preference. Possible configurations designed were a coffee shop vehicle, social bar vehicle, hotel room vehicle, and office vehicle.
2. Segmented Space-Based Ride-Share Solution: This provides both a private and personal spot through segmented spaces. Passengers who want to spend their commuting experience are matched with people who requested the same; this solution aims to solve the unsatisfied need of quiet users for ride-sharing services. This solution also provides a modular option, allowing the passenger to interact with other riders who also requested a social experience. Through the construction of automatic configurable partitions, the same physical car will allow different types of people to experience a vehicle that is adjusted to their preferences.
3. Personal/Ride-share Automatic Configuration: A completely automated vehicle that will allow passengers to perform several activities while having a ride. The main idea is to enable people with the

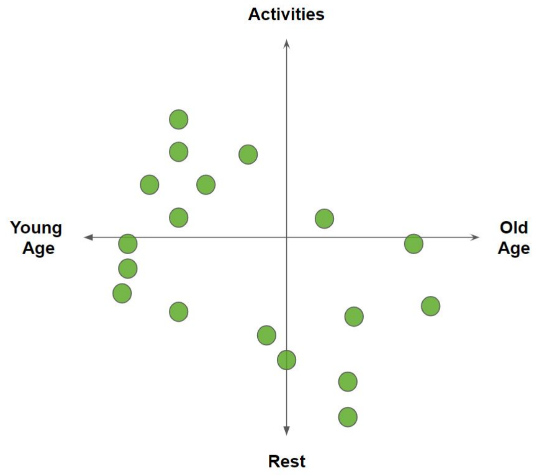

Fig. 3: 2x2 Analysis over peoples interest on activities in a car according to their age. Figure shows a trend that older passengers prefer to rest more during their ride.

ability to configure their vehicle at will (collapsible tables, rotating chairs, personalized entertainment systems) and then return to the default mode when the vehicle is parked.

Our expert feedback provided valuable insights in our concept selection process. Even though changing the expectation of regular rides was considered a valuable and innovative option, the variable expectation vehicle solution was discounted because of its difficulty to implement into the current automobile industry. For the personal/ride-share automatic configuration solution, industry experts warned us that this idea would be challenging as the targeted user base was too broad for a feasible solution. The solution was trying to tackle multiple problems at the same time and may result in a solution that is undesirable to any one user-base. The partition-based ride-share solution was recommended by the experts for further development. It was interpreted as a practical and short-term implementable solution that could be useful in the near future of ride-sharing services.

2.3 User Testing

To understand the strengths and flaws of the proposed concept, different user tests were generated using multiple Minimum Viable Products (MVP). The objective of this method was to replicate on a real-scale the concept through a low fidelity prototype. With the creation of the MVP, fast product testing was possible, helping to better understand users reactions and pain points. Through user testing, the configuration of the prototype was iterated several times according to the users' feedback, recommendations, and concerns, collected through interacting with a diverse group of users. The final product obtained in this process is the resulting version of the iterated prototypes.

The first round of user test was utilized to determine the reactions of users when they were on-board a partitioned vehicle, as shown in Fig. 4a. The goal of the test was to determine whether the partition helped improve the privacy, comfort, and safety of the user. The user test consisted of ten participants, all of whom experienced the partitioned vehicle on a fifteen-twenty minute ride to their destination within a five mile radius from their pick up point. Initial perceptions from the users were collected right after the ride was completed along with an in-depth survey.

2.4 User Testing Preliminary Results

We present the results from the interviews, user testing, and an analysis of the recordings of the user testing. By grouping these together, we can devise a solution that encompasses the needs of the users. The interviews and recordings are kept anonymous to protect the test subjects, allowing them to provide honest and true feedback during their responses.

2.5 Survey Analysis

From the surveys, the partition was rated at an average of 3.7/5 for comfort, 4.2/5 for privacy, and 3.1/5 for safety. From the user feedback, some key insights on the design included:

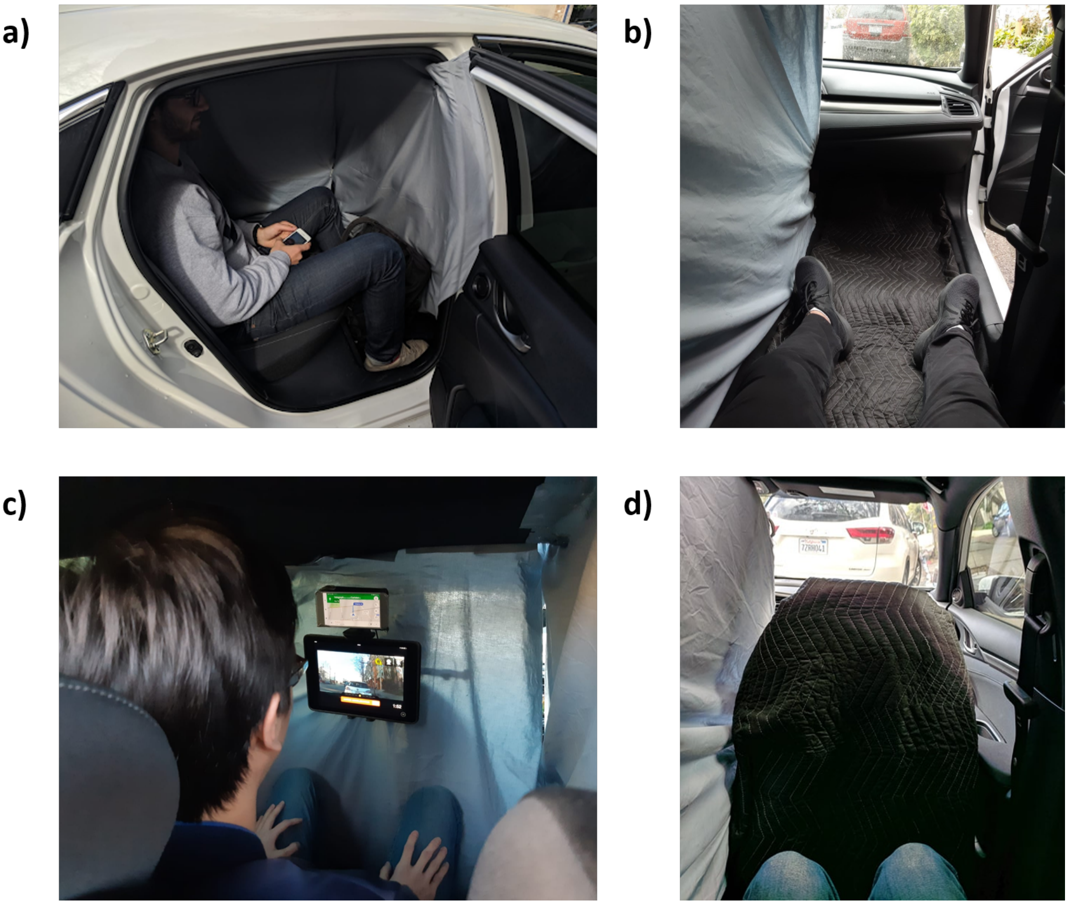

Fig. 4: Iterations and four different setups for experiential prototyping from the generated concepts. a) Demonstrates a completely enclosed private space with partitions. b) Demonstrates a premium user seating configuration with removed front seat and open leg room, more than doubling the physical space for the user. c) Configuration A demonstrates an enclosed space but provides the user with real-time information and tracking of the vehicle and surroundings. d) Configuration B demonstrates open field of view for live vehicle and surrounding status but physical space was restricted to the default size.

- Positive
  - Quiet environment to get work done
  - Personal space without being disturbed by others
  - Prevents awkward situations where the user does not want to talk to others sharing the ride
- Negative
  - Safety concerns, due to not being able to see the driver or situate oneself on the road
  - Feeling of awkwardness caused by not knowing whether there is someone sitting next to you
  - Lack of windows created a claustrophobic feeling

The feedback received proved that the initial goals of creating a quiet and personal environment for the user during a commute was achieved. However, other negative features of the design were also discovered. To address the negative features of the design, a second round of user testing was conducted.

A/B testing was utilized to determine whether having a user looking at a screen that projects the front view of the vehicle is able to help improve the claustrophobic feeling and safety concerns addressed in the previous user test. The experiment was set by conducting five user tests on each of the two setups. The first setup, Configuration A (Fig. 4c), consisted of a partitioned space on a vehicle with monitor displays that show the frontal view from the vehicle along with the route information provided through Google Maps. The second setup, Configuration B (Fig. 4d), consisted of a partitioned space with a partial view of the front windshield.

Comparing the results from the two tests, it was found that Configuration A created a better feeling of privacy compared to Configuration B. Configuration A was rated at 4.2/5 for privacy while configuration B was rated at 3.6/5. Configuration B, however, was rated higher on comfort. Configuration B was rated at 3.8/5 for comfort, while configuration A was rated at 3.6/5. Analysis of the recorded videos of the user test and the comments addressed by the users showed that although Configuration A helped situated the users with the outside environment, the screen increased their sense of motion sickness. Furthermore, the location of the screen caused the user to constantly stare at the screen over the course of the ride.

Through the feedback from the A/B test, it was determined that the screen-based perception mechanism was not sufficient at addressing the claustrophobic feelings and safety concerns originally expressed by the users. The final solution, therefore, will utilize a different mechanism to allow the users to have a wider view of the outside environment.

Another feature that was tested was the prime seating arrangement (Fig. 4b). This was to see if users were willing to pay extra for the extended space and legroom. Five users were tested on short fifteen to twenty minute rides and their initial thoughts and ride experience were recorded through video capture and surveys.

Analysis of the user feedback found that four out of five users enjoyed the extra legroom and were willing to pay more for the extra legroom, especially on a long ride. One female passenger,however, felt that the extra legroom could not be effectively utilized by her. Although this looks like a promising solution, more testing will be required before implementation into the final solution.

2.6 Video Recording Analysis

Nine out of the twenty five user tests were recorded using a GoPro Hero 5 Black stuck onto the lateral window. Techniques similar to related research papers were used in this section. The recordings were used as a complement of the post test survey to get a better understanding of the user experience under the commuting scenario presented [16]. Each video was transcribed into a table containing relevant user quotes and actions (See Appendix: Video Analysis), identifying the specific time stamp when they happened. For a better analysis, they were clustered afterwards into two subgroups: Positive Experience and Negative Experience [17]. Five videos presented positive outcomes and all of them end up giving a good evaluation of the solution in the post survey. Out of the five, three were B+ tests (which provide the users extra space and positive outcome was expected) and three B tests (where the field of view was wide, including half of the front shield window and all the right hand side of the car). From the positive comments and activities, the most significant were: ”I love the space”, ”I would pay for it if its a long ride or i'm tired”, ”passenger closes his eyes and looks relax”. On the other hand, two out of the four negative experience videos were in A testings. This outcome is related with the conclusions from the survey, were a screen based solutions was not comfortable for the users. The next two negative videos are for B and B+ tests, were the main concern was the partition, making the passenger experience an awkward and uncomfortable ride. From this videos important quotes and actions were: ”I feel like i am in prison”, ”I don't like the curtain, I feel trapped (...). It's like a wall”, ”Its kind of claustrophobic”, ”Users doesn't seems relax, he is looking fast to different directions”.

3 Research Insights

The increasing trends in shared spaces has presented a need for safety, privacy, and comfort. After performing 20 in-depth interviews, the need was defined and categorized. Following, a thorough list of concepts was generated, clustered, and finally, a solution was selected after considering research and industry expert feedback. We implemented this solution to user tests with an MVP to obtain feedback directly from end-users. From this HCD research we ended up finding different valuable insights that can contribute to the mobility industry. The first conclusion obtained was that users mostly prefer a private ride rather than a pool service. The main reason why they use ridesharing services is because of the lower price compared to a personal vehicle service. Within the group of people that take the pool alternative, there are two main subgroups: Private and Social, defined as their willingness to talk to the other passengers during the ride. From the group that prefer to remain quiet during the ride, they were more likely to use their own personal car instead of a rideshare whenever it was possible. Ridesharing services were only used when it was strictly necessary. The feedback from this group demonstrated that all the solutions that addressed privacy through a segmented space was appreciated by the users, rating their experience as better than the one they have experienced in previous shared rides. On the other hand, people that were more eager to share with the other passenger completely dislike being apart from the other riders, defining the ride as awkward and uncomfortable. The scope of the next section is to explore new approaches in the search of a transportation space able to be adequate to users preferences by generating social and segmented spaces within a same flexible vehicle.

Four different personas were constructed: Private Patty, Exhausted Edward, Active Andy and Accompanied Anne (See Appendix: Journey Maps). Each of them represent a particular individual containing the main user's pain points identified along the research detailed above. Journey maps were generated for the four of them describing each of their daily activities, thoughts and commuting preferences and behavior. The proposed solution to be described below aims to create flexible ridesharing scenarios able to address each of the personas needs.

4 Proposed Solution

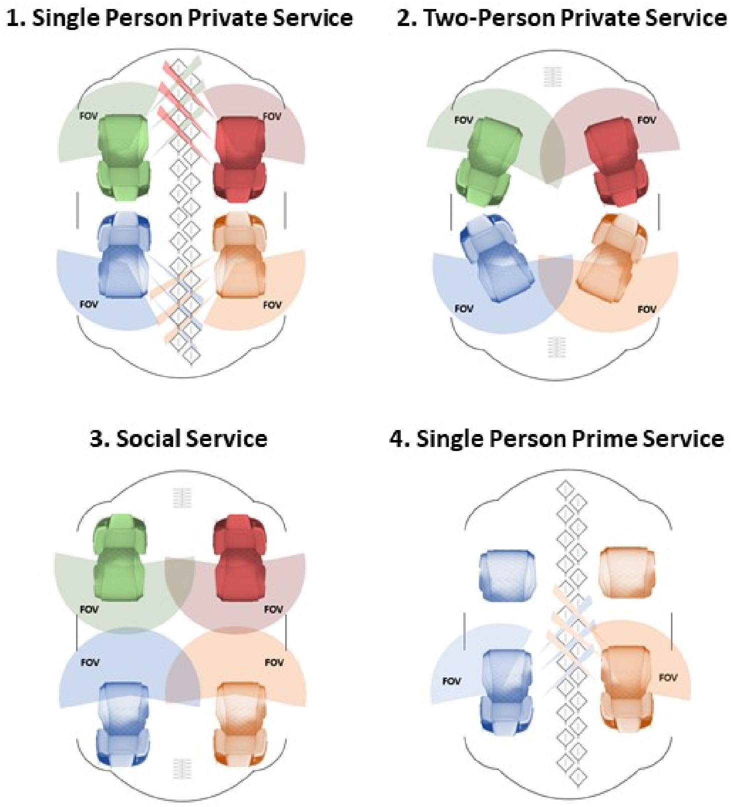

Fig. 5: Field of view (FOV) configurations for partitioned and social arrangements. a) Demonstrates deployed partitions, restricting the FOV of adjacent passengers. b) Partitions are collapsed but seats configuration discourages social interaction. c) Collapsed partitions and reconfigured seats for socialization.

Mass occupancy of rideharing services might help provide new ways of interacting with others. This interaction, however will be determined and dependent by the scenario and perception of the interior of the shared vehicle [18]. From the feedback gathered, we have synthesized the final solution (Fig. 5), which will be a commuting concept vehicle able to automatically modify its interior configuration. Automatically-deployable partitioning will be used to create different segmented sub-spaces. These partitions will be able to govern the field of view for all passengers to enhance comfort and safety, as well as provide a physical separation to increase privacy. The separations are designed as pillars with a diamond cross section, which will be actuated to collapse (Fig. 5). The rendered image of the proposed prototype can be seen in Fig. 6.

As Figure 5 illustrates, this solution allows four kind of configurations within the vehicle. The first one (Single Person Private Service) is focused on Private Patty, who would like to have a personal space while commuting, without needing to interact with strangers. Moreover, configuration number two will be for people like Accompanied Anne, which will prefer a personal space while riding a car with a friend or couple. In the case of Social Service, the configuration is design for people like Active Andy, who wants to interact with another passengers that are also willing to talk to him during the ride. The position of the seats and the collapsed partitions encourage user's interactions. Finally, the configuration number four is inspired by Exhausted Edward. With this option, long distance commuting can be used to have a personal space to rest and relax during the trip.

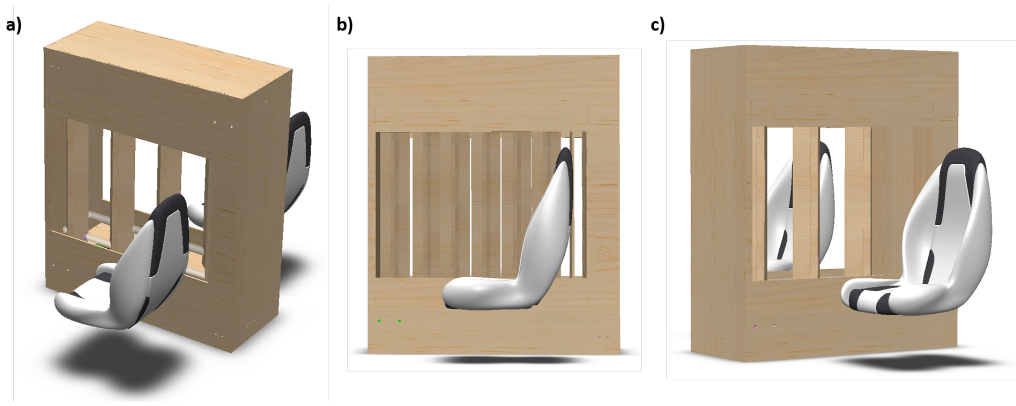

Fig. 6: Rendered image of partition system. a) Isometric view of partition system. b) Front view of partition system, demonstrating field of view blocking when the viewing direction is perpendicular to partitions. c) Slanted view of partition system, demonstrating field of view of a seating passenger.

4.1 Existing Solutions - Patent Analysis

Reconfigurable partitions have been previously utilized in many locations, such as building spaces [19]and cubicles [20], to optimize the space for different scenarios. The concept of utilizing this design in vehicles, however, have been mostly overlooked.

Partitions have been previously utilized in vehicles to help segment the space within. These include partitions to improve safety in taxis [21] [22], a partition to divide children in the rear seat [23], and a small partition placed in between the rear seats to increase the sense of personal space for rear-seating passengers [24]. Our proposed solution provides a new use case that has not been previously explored. By providing a collapsible partition with selective field-of-view, our proposed solution provides a flexible design that is able to accommodate different users' needs. The partitioning can provide single users a safe and private environment, while also providing an open space for social users.

4.2 Partitions

Figure 6 shows how the partitions will be deployed and how it affects the passengers field of view. The partitions have been designed to be visibly semi-permeable. When users are seated, they cannot actively see the passenger on the other side of the boundary (Fig. 6 c)). This allows passengers to still have a field of view on the right side of the vehicle but provides the privacy with respect to the adjacent passenger. The only way for adjacent passengers to see each other is by leaning forward and looking diagonally backwards. The strain induced on the passengers body during this position is not sustainable and is therefore not the preferred position a passenger will be maintaining.

A prototype was developed to showcase the partition concept. The supports, frame and partitions were laser cut, while the partition hinges were 3D printed with embedded torsion springs. The springs provide an accordion-like mechanism, which allows for the partitions to be passively deployed. The partition is designed to be actuated with two belt transmission systems, on the top and bottom of the partition. Two belt transmission systems are utilized to ensure uniform deformation of the partitions when they are fully collapsed. A stepper motor is utilized to actuate the belt, which drives the partition to either a fully deployed or fully collapsed configuration.

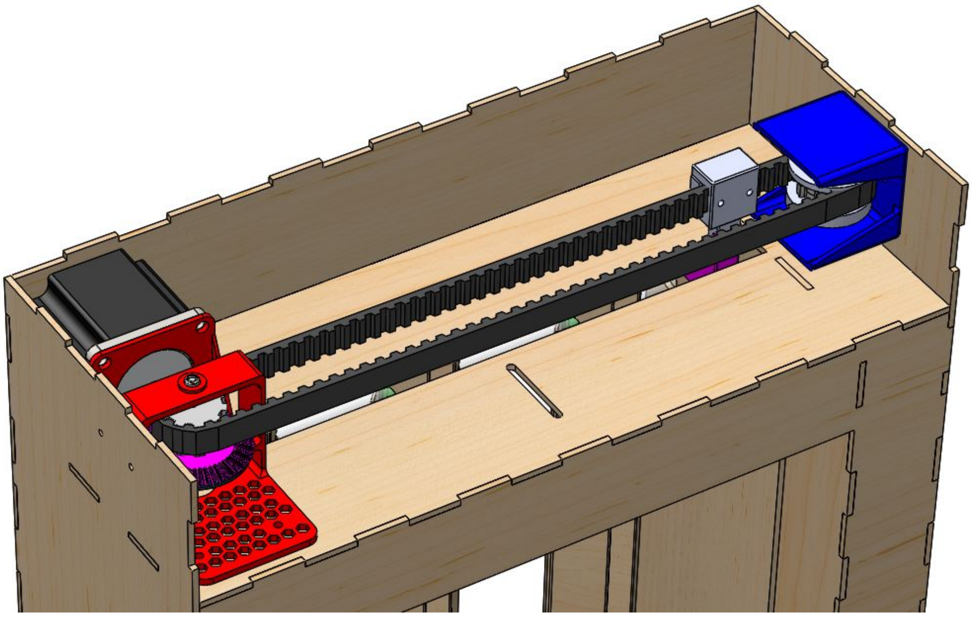

Fig. 7: Rendered image of belt system. A stepper motor is attached to a 90° bevel gear, which drives the belt system to allow for the belt to actuate and compress the partitions.

4.3 Rotating Seats

The four car seats will be able to rotate to each of the four configurations. They will be connected in the bottom to a servo motor that will be able to change the direction of the chairs. As Fig. 5 illustrates, chairs will rotate to obtain the four possible configurations.

4.4 Doors

Given that partitions will be segmenting the car, doors will be positioned in the front and in the back of the car. Four different Gullwing doors will be in front of each seat. By this mean, users will be able to get into a particular chair of the car in any side of the rode. The selection of the seat will be assigned by the ridesharing software. Riders will be notifie through a map display of the car in their mobile application. In addition, the door is going to open automatically when the user approaches the vehicle, making it easier to the user to access to the car.

4.5 Software

An Arduino UNO with a Bluetooth module is used to control the seating configuration and partition deployment. A mobile application has been developed to communicate over Bluetooth to the micro-controller to generate the desired configuration in the prototype.

5 Alternatives and Future Work

To create a segmented subspace within a car that also allows social interaction among riders that prefer talking with other passengers, different approaches can be developed. The goal of this section is to present alternative solutions that can be explored in order to create solutions that satisfies users' mobility needs. These alternatives serve as future work and can be expanded from the insights we gained from this research.

5.1 Personal Commuter, individual experience

One alternative that could generate value for the actual users is to create a commuting vehicle focus only in riders that prefer their own personal space. The daily hour spend to arrive the workplace is often one of the little time that workers have free and for themselves during the weekdays. Being able to use it

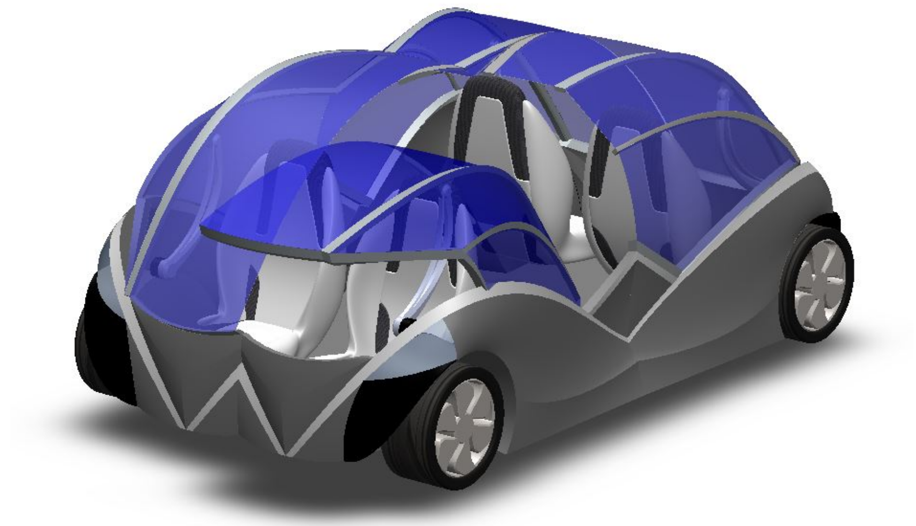

Fig. 8: Gullwing doors of concept vehicle. Design derived from courtesy of Kir Ari.

under their own willingness and by they own is what this solution is aiming to give them. This concept is based as well in physical partitions, but in this case, a completely partitioned space. The idea is to recreate the four windows of the car in the wall on the surrounding of the passenger by using 3D LED Screens. Displaying a real time image of the exterior, the space that each of the four riders will experience will be a representation of a single passenger car, having visuals a 360 visual space. If we recall from the results of the A testing conducted, a screen based solutions yielded in motion sickness problems. Therefore, the projections should be computationally modify to simulate real depth of the objects in the outside (taking advantage of the 3D Led Screens capabilities). User testing will be required to proceed with this type of solution to find the best display option.

5.2 Selective Lighting

Privacy perception can be created by using different lighting techniques. The objective of this solution is to give the passenger the ability to change its lighting according to its willingness to socialize with the other riders. Therefore, by smartly positioning different lights inside the car and keeping the interior of the vehicle dark by utilizing tinted windows, different subspaces can be created.

5.3 Modifiable Seat Angles

Another way of addressing peoples privacy and comfort while commuting is by changing seats angles. The main idea of this approach is to encourage or discourage socialization according to the passengers preferences (Fig. 9). This solution would also require having rotating seats facing each other, so user testing evaluating this configuration will also be needed.

Therefore, the configuration situated on the left (Fig. 9a) encourages social interaction among the riders, while on the other hand, the configuration on the right (Fig. 9b) discourages people socialization by facing their seat towards the lateral window.

5.4 Modified Commuting Expectation

A different approach that can be explore is changing commuting expectations. To do so, the main idea is to recreate a space inside of the vehicle that simulated different experiences related to different behaviours. Possible ideas that can be addressed would be a coffee bar, working space, bar, grocery store, or resting room vehicle, that embed the user into a particular scenario during commuting. The main goal is to let the people invest their commuting time in an activity that is either enjoyable or productive, letting them choose which kind of transportation scenario they would prefer as a transportation service. Comparing it to previous recommended approaches, coffee bar and bar vehicles would be designed to encourage socialization, while working space and resting room vehicles would be addressing the needs of passengers who wants a private segmented space.

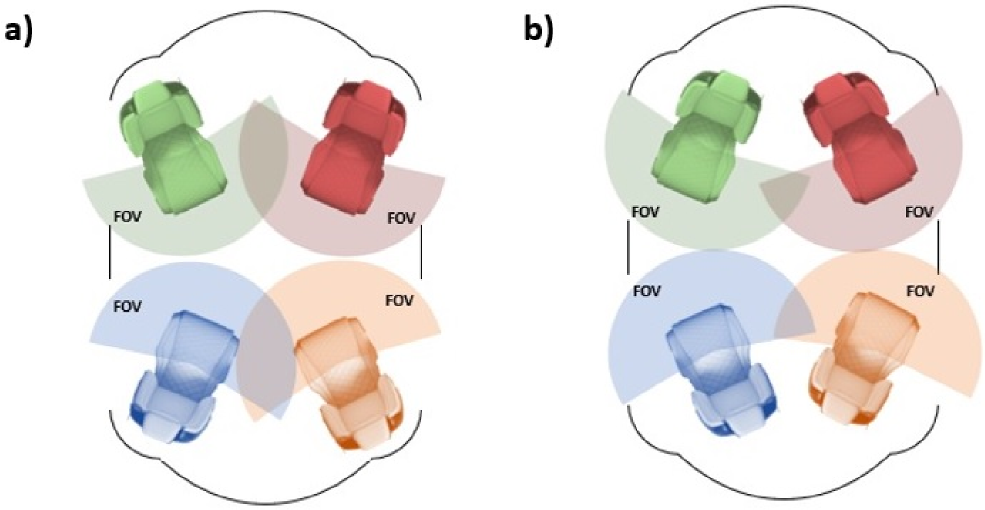

Fig. 9: Possible configuration proposal for representing different scenarios inside of a vehicle. The configuration on the left hand side (a) would be deployed when commuters prefer interacting with the other riders. In the case of the right hand picture (b), orientating the seats towards the window will discourage communicating with the other passengers if they are seeking a private ride.

6 Conclusion

Our proposed solution brings together the various needs of passengers in shared mobility spaces to open new opportunities for flexible experiences. We implemented human-centered design methodology to address the concerns and develop a partition-based solution intended to impact the future of autonomous ride-sharing experiences. Companies like Zoox, for example, are changing the layout configuration of vehicles, claiming that the future structure of autonomous vehicles can be simplified. Since they will be electric vehicles and autonomous, there is no need for an instrument panel or dashboard. Our final solution aims to address the conformation that caters to the user's needs, employing a more human-centered approach. Whether our research is implemented in five years or 20, our proposal can be implemented in both current vehicles as well as future redesigned vehicles. Preliminary user feedback from an informal project design showcase have informed us that there is indeed an impact in applying human-centered design to address passenger needs during shared mobility solutions.

7 Limitations

There are inherent limitations in our conducted study. First, the demographic of interviewees in the first round of interviews could be further diversified in age and background. It is possible that different user needs could have been identified under a more broad set of participants. In addition, given safety and resources constraints, users that contributed to our research in user testings were only graduates students of the Master of Engineering at University of California, Berkeley. The outcomes of these tests may be biased because of the particularities of the test group. Moreover, the physical partitions deployed inside of the car were made of fabric. This impacted in the transparency of the division, affecting the segmentation experienced. Also, the total amount of user testing (twenty five) was not large enough to develop significant statistical comparisons. In the case of the Video Analysis, only nine tests were properly recorded. Given camera storing capacity and lack of light of the footage, some recordings were discarded. Finally, considering our time constraints according to our final publication deadlines, the final solution belongs to an iteration of the user feedback instead of a final product. As a next step, the partial partition concept might be tested in a real scale inside a vehicle while commuting. By this mean, user feedback will bring valuable insights about the value of this solution, and the possibility of implementing it into a real ridesharing service.

8 Acknowledgements

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Appendix

Video Analysis

User	Minute	Quote or Action	Test Type	Video Analysis Summary
2	0:46	"I love the space"	B+	Passenger looks comfortable, enjoying his ride. He seems relax while he awaits to arrive home.
2	1:27	"This is a VIP space"		
2	6:40	"Yes i would pay more for the extra space"		
Total Length	7:09			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
3	1:13	checks his phone since this moment to the end of the ride	B+	Positive outcome. He liked the space and the ride, however, he would prefer having a better angle view in the side the partition was blocking the view"
3	6:02	"I would pay for it if its a long ride or im tired"		
3	5:53	"Pretty comfortable (...) specially because i had a lot of space"		
3	6:30	"However, i would like to have a little bit more of view in the front. (...) more angle of the view in the front shield"		
Total Length	7:26			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
5	7:53	riders gets in the car and look smiling and surprised	B+	Rider looks relax, but video got interrupted at the beggining.
5	9:10	Rider looks relax staring through the front window		
5	9:16	Recording is interrupted		
Total Length	1:23			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
7	0:19	rider looks surprise and smiling, a little bit confused as well	B	Rider looks confuse and surprise. He smiles all the time. Recording is interrupted after 57 seconds, so the rest of the video was not stored.
7	0:21	stares at the screen for the rest of the video		
Total Length	0:57			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
8	0:05	Rider looks excited about the ride	B	Passenger looks relax and enjoying the ride. Most of the time he is either looking outside through the windows or chatting through his phone. He looks comfortable.
8	0:19	"What if the other passenger start saying wierd stuff to you in the ride"		
8	0:43	"Can we talk to u or we cant?"		
8	2:13	passenger closes his eyes and looks relax		
8	up to min 6	Looking outside through front and lateral window		
8	7:54	Passenger seems to enjoy the music		
8	8:28	He starts using his phone		
8	11:45	stops using his phone		
Total Length	12:20			

Video Analysis of Positive Experiences

User	Minute	Quote or Action	Test Type	Video Analysis Summary
1	0:31	Confuse About the interior but smiling	A	Passenger looks uncomfortable in the segmentated space. The light of the screen annoyes him a lot in the dark. It looks like he experience was bad overall
1	1:03	"I feel like im in prison"		
1	1:29	"what is this ipad for?"		
1	2:44	puts his hand in front of the screen because lights annoyed him		
1	5:34	looks to the camera and so a hello signal to it		
1	6:57	puts his hand in front of the screen because lights annoyed him		
1	11:00	puts his hand in front of the screen because lights annoyed him		
1	11:14	puts his hand in front of his face and closes his eyes		
Total Length	13:08			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
4	0:26	"what am i suppose to do"	B+	Passenger seems neutral with respect to the scenario. She would use it under certain circumpstances like groceries or long trips, but in a regular ride she feels wierd ("trapped")
4	1:01	"Am i recorded?"		
4	1:24	Uses her phone		
4	1:41	Takes a picture of the configuration		
4	2:05	"I wish the chair would be more forward"		
4	2:27	"Its too back, there is too much space"		
4	6:30	"Its feels way better than having a chair in front of me"		
4	6:37	"I dont like the curtain, i feel trap (...). Its like a wall"		
4	7:08	"Just feels kind of wierd"		
4	7:30	"I would pay more if im coming from a groceries store or if its a long trip"		
Total Length	7:48			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
6	0:19	"Am i suppose to talk to aaron?"	A	Rider looks confuse and awkward. He thinks is claustrophobic. He spent the whole ride staring at the screen to see the rode.
6	0:27	"There is someone in the drivers seat?"		
6	1:19	"This is kind of wierd dude"		
6	1:30	interacts with the camera		
6	1:30-2:55	Looks at the screen		
6	2:56	"Its kind of claustrophobic"		
Total Length	7:36			

User	Minute	Quote or Action	Test Type	Video Analysis Summary
9	12:50	User seems confuse about where to look.	B	Users looks uncomfortable at the beggining, he seems confused and awkward. After a couple of minutes he looks relaxed like in a quiet commuting scenario.
9	13:40	Users doesnt seems relax, he is looking fast to different directions		
9	14:29	Passenger stares at the front window and starts looking relax. Stays this way the whole ride		
9	3:57	Starts using his phone		
9	4:27	stops using the phone and looks at the front window for the next of the ride		
Total Length	11:33			

Video Analysis of Negative Experiences

Personas Journey Maps

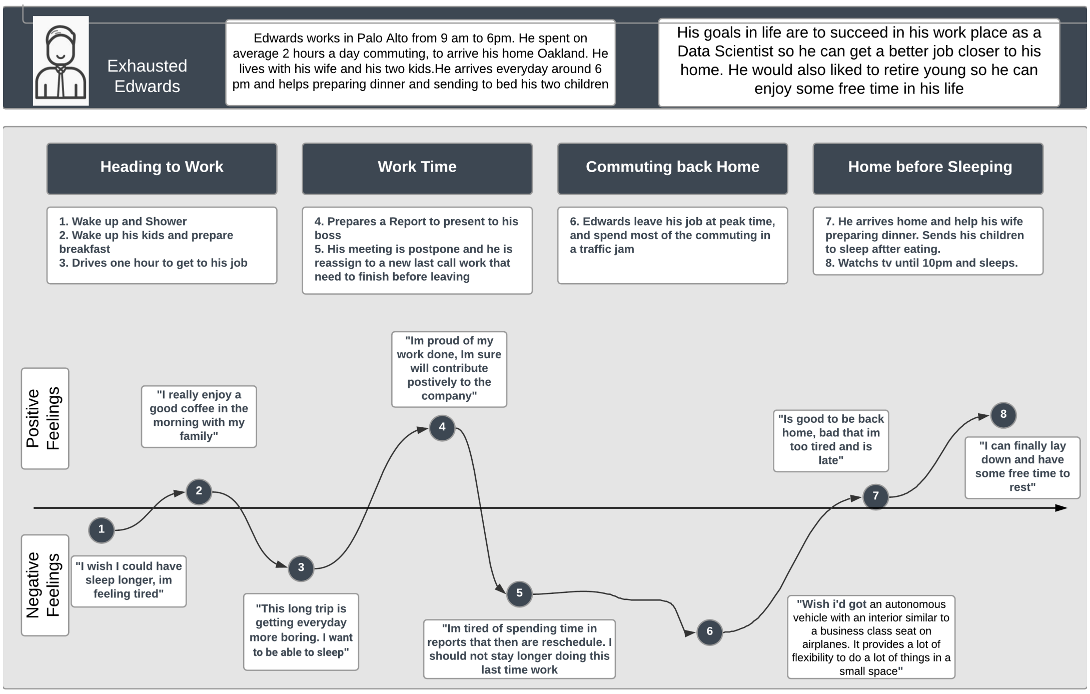

Fig. 10: Journey Map of Exhausted Edward Personas

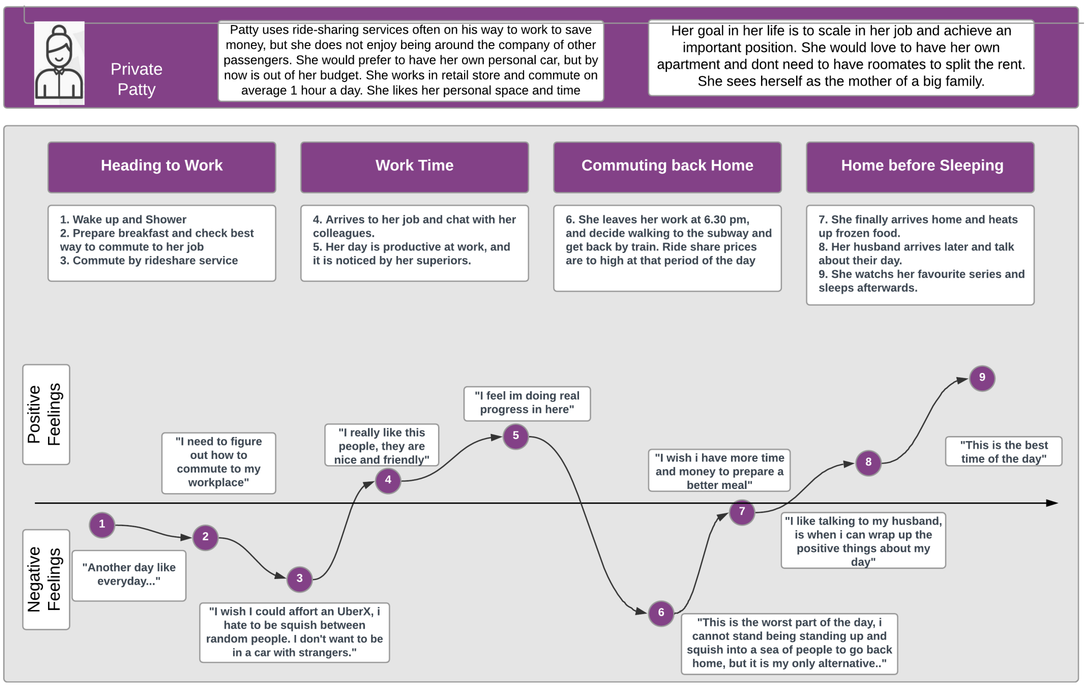

Fig. 11: Journey Map of Private Patty Personas

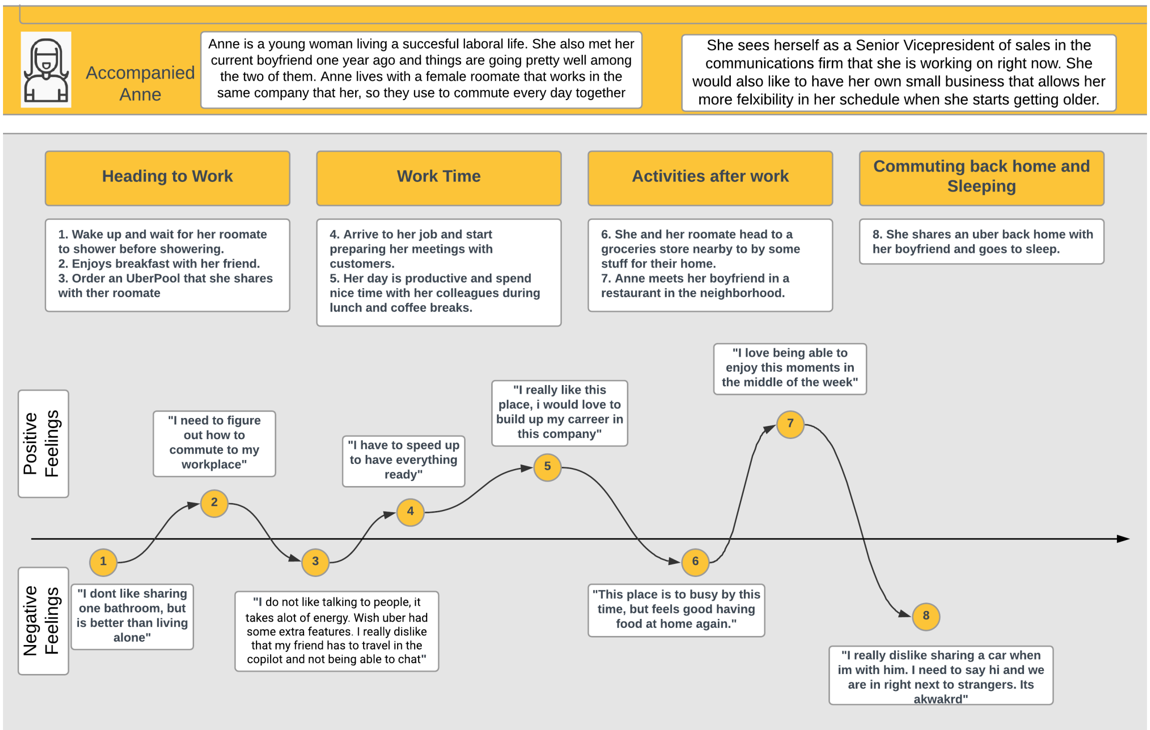

Fig. 12: Journey Map of Accompanied Anne Personas

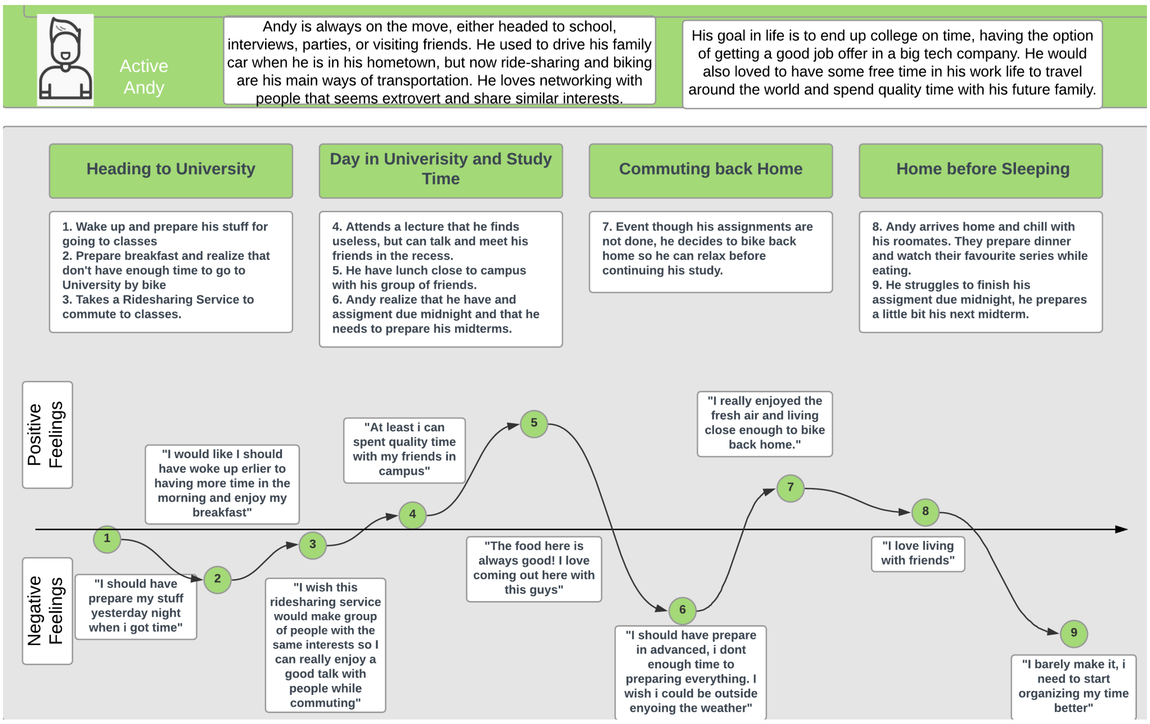

Fig. 13: Journey Map of Active Andy Personas