Autonomous Vehicle Futures

Designing Experiences that Enable Trust and Adoption

Jeremy Bass
Industrial Design Master's Thesis
RISD, 2018

Contents

Abstract

This thesis is an investigation of the user experience design necessary for a fully autonomous vehicle that would enable trust and adoption of autonomous vehicle-based services. Autonomous vehicles are destined to revolutionize mobility, yet few companies are focusing on how people will best use these new autonomous-based services. This thesis used various forms of user testing to understand user's expectations and hesitations for riding in an autonomous vehicle. These tests included improv workshops, surveys, interviews and a simulated autonomous vehicle service ride-along. Research revealed that user's primary concerns were travel time, comfort (spatial and privacy) and personal safety. These concerns culminated as a series of proposals for how vehicles will communicate trip status to its passengers. Establishing a trustworthy service that would lead to adoption is possible if designers treat the design of experiences as 'interactions with robots', not as cars.

Special thanks to:

[1] FXFOWLE & Sam Schwartz Engineering. "Public Square". *Archdaily,* Archdaily News, 22 July. 2016

Concept illustrates example of a plug-and-play scheme that transforms the street for New York streets and pedestrians made possible by autonomous vehicles.

An Autonomous Future.

Enter: Autonomous Vehicles

We are on the verge of a revolution in transportation, one that will transform our personal mobility. Autonomous vehicles (AVs) promise safer and more efficient transportation as well as new business opportunities. The introduction of AVs onto the landscape can help facilitate future design and planning of cities for humans rather than cars. Our time spent driving, finding parking or dealing with traffic congestion can now be allotted to other tasks such as being more social, work, spending quality time with family and other ways yet to be explored.

However, it is likely that people will still prefer to drive their own vehicles and are not likely to readily adopt AVs. The adoption of AVs will be difficult due to people's inability to relinquish control of their own vehicle and to trust the AV. These AVs are essentially robots that will have no steering wheels once technology is further refined. This lack of direct control of the vehicle makes it easy to understand why people would not trust an AV - because there is no visible operator or control element. Without a physical connection to the vehicle, the entire experience becomes ambiguous.

This ambiguity must be eliminated if we expect people to trust AVs. Reframing our interactions with vehicles can clear the path for new interpretations of trustworthy transit.

To enable the adoption of autonomous vehicles, user experiences should be reframed as 'interactions with robots', not as riding in cars. Designers have long worked on creating trustworthy interactions between humans and robots. They offer a potential precedent for creating user experiences for trustworthy autonomous vehicle-based services. Viewing AVs as 'interactions with robots' provides non-automotive designers with a new framework to design AV

[2] Volkswagen. "Sedric". *Cnet*, Chris Paukert, Road Show by Cnet, 13 March. 2018

experiences. Redefining mobility experiences will call for customized user scenarios that are not reliant on the constraints that automotive designers traditionally face.

To aid in the adoption of AVs, we need to address issues of personal safety, comfort and travel time using an overlap of traditional interaction design principles and behavior principles from the field of human-robot interaction (HRI). If we (designers) consider the design of AVs as interactions with robots, then we can start to visualize, predict and design the experiences we want to have and the interactions that we need. Currently, the majority of AVs in operation are a rehash of existing transportation formats, i.e. buses, shuttles or traditional cars. With this new approach, transportation can be reimagined and AVs can depart from 'traditional car design' conventions. With this departure, AVs have the potential to strengthen public transit systems by creating opportunities for more diverse applications that are tailored to resident needs. AVs can either operate on fixed routes like existing buses, adaptive routes based on demand or as a ride-sharing platform.

The emergence of a diverse, multi-modal transit system will beckon for new form

[3] Navya. "Navya Arma". *Stuffi*, Vincent Bouvier, Stuffi, 16 Feb. 2016

[4] Google. "self-driving car prototype". *The Verge,* Sam Byford, The Verge, 15 May. 2015

[5] Local Motors. "Olli Autonomous Bus". *Car Design News*, Farah Alkhalisi, Car Design News, 5 Aug. 2016

evolutions of public transit. These forms may be for individual transport, a group of four to five passengers, or a small bus with a capacity of 10-12 passengers. Due to the potential varying forms of AV transport, the success and adoption of these vehicles not only relies on technological efficiency and accuracy, but on well-designed user experiences (physical & digital).

Adoption and Trust.

How do we get people into these robots?

Despite the fact that AVs can offer freedom from mundane driving tasks (such as parking and sitting in traffic), the adoption of AV based services will be challenging, especially in the United States. As a country with a population that is largely dependent on personal vehicle ownership for its primary method of transportation, the most difficult challenge will be for people to give up the ability to control their own vehicle. Cars are an expression of identity and provide a sense of security in most cities that lack sufficient public transit. In 2016, over 17.6 million cars were sold in the United States, a record high for the seventh year in a row [6]. That is a lot of cars.

My past experience as a car salesman for Toyota revealed that a huge portion of car sales rely on brand loyalty and trust. Most often, this trust or brand loyalty is not placed in the dealership providing the services, but the car and company itself. Fortunately, I worked for Toyota which has a strong loyal customer base, but even then customers can be suspicious of what you're selling. Throughout the entire selling process, I had to place myself in the customer's shoes and tailor the experience to match their expectations. The customer's trust relies not only on an understanding of how the vehicle operates, but also on anecdotes and personal experiences collected from friends and family members. It was not uncommon to hear customers say something along the lines of "My mother always bought a Toyota. It got me through college. It just works."

It is easy to imagine how anecdotes could potentially hinder AV adoption, which is why it is imperative to design effective user experiences "that just work."

As a salesman, I found this challenge became more critical as the user experience of the vehicle started to evolve with the

Representation of traditional car design conventions that confines information.

[7] Toyota. "Toyota Rav4 Limited Interior". *the truth about cars*, Alex L Dykes, The Truth about Cars, 2016

standardization of touch screens and the incorporation of advanced driver-assist technology. Often, customers would return asking for help with their purchase or refuse to buy because it was too much of a change from their previous vehicle. Since issues of trust and adoption of evolving technology have been long-standing even in traditional cars, establishing a basic level of trust in AVs will be difficult, especially without a "salesman" to iron out hesitations. This speaks to the importance of a well-defined and designed service.

These enduring conventions are essential physical elements or cues that control the overall design of traditional vehicles. For example, vehicle interiors (consequently vehicle experiences) are dictated by the placement of the steering wheel. Any vehicle information (such as speed or fuel level) is positioned directly behind the wheel, rendering it useless to anyone not actively steering the vehicle. Entertainment or navigation controls must be within arm's reach of the driver's position at the steering wheel and/or the controls are duplicated on the steering wheel. The elimination of steering wheels alone opens the door for new arrangements of vehicle information and entertainment options. All passengers in the vehicle will be able to control and dictate their own experience, rather than have it be controlled by one person. Designers can start experimenting with whatever information is most pertinent to passengers. AVs free us from the traditional physical limitations of vehicle interiors and we can begin to reimagine that too.

It is with this interest in re-imagining the ride experience that I visited the Uber office in Pittsburgh. There, I was able to ride in an AV intended to be used as a ride-hailing taxi service (via an app). This experience helped me understand what must be done to address the lack of user experience in

"My mother always bought a Toyota."

"It just <u>works</u>."

"It got me through college."

- Anonymous Toyota Loyalists

an AV. Understandably, Uber was not yet ready to begin designing extensive user experience elements. The user experience was essentially non-existent outside of an ipad.

I did not have to be overly concerned about miscommunication or making a mistake as an employee was there to guide me. As the car pulled up, there was no way of identifying if it was the correct vehicle. The safety driver rolled down the window and asked for our names to confirm that the right people hopped in. My only source of information (other than talking to the safety driver) was a small ipad between the front seats. I had to lean to the left and far forward to view our route status.

On the ipad, the passenger had access to two screens. One was a modified visual of what the car can 'see' (computer vision) paired with some vehicle status information such as directional cues, estimated arrival time, speed, time, pull-over button, distance traveled under self-driving mode and a bar that would toggle on or off depending if the car was in self-driving mode. As the car drives along, the visual is constantly updated. As the car detected objects in the surroundings such as other cars, those detections would show up in blue to signify to the rider that the car could 'see'. The other screen option is the same computer vision visual, but with your destination highlighted, arrival time, a selfie button and Q&A section.

The majority of this information is important to convey to the passenger, but how it is communicated is critical. The major fault of this setup is largely due to the volume of information crammed into a small ipad screen far from the passenger's line of sight. In the middle of the screen, the passenger is given directional cues corresponding to the direction that the steering wheel is turning. This diagram is
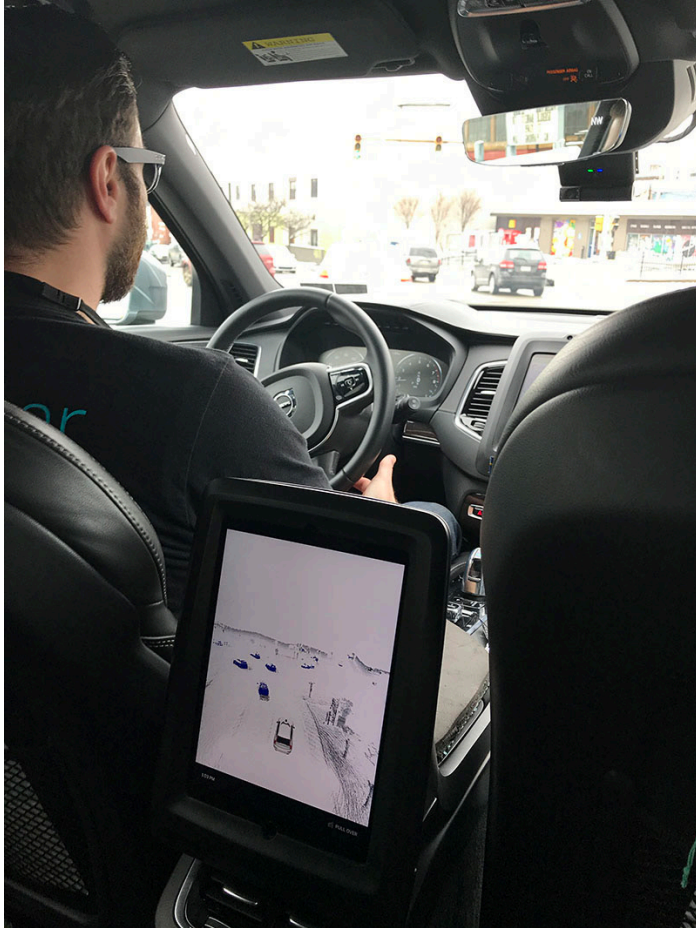
[8]
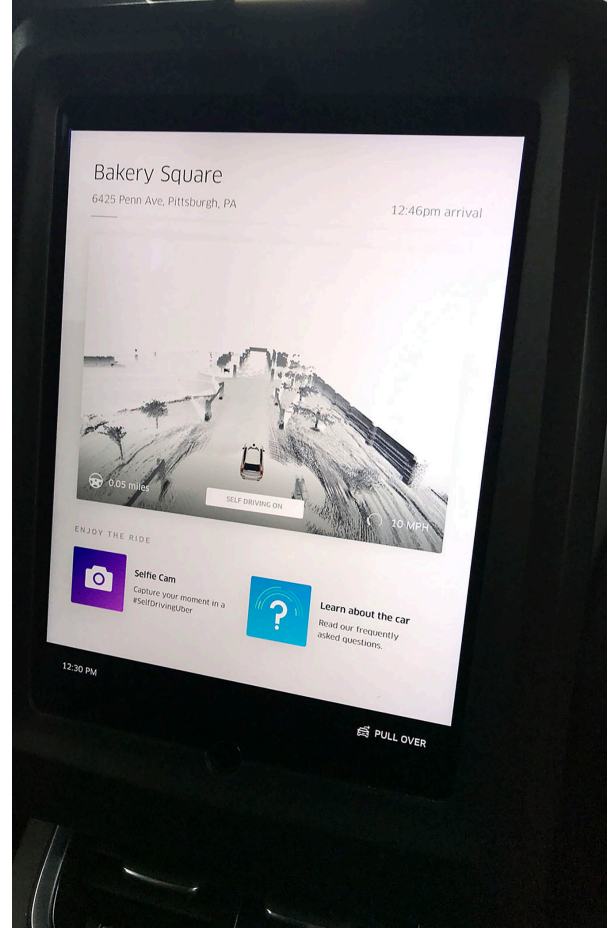
[9]

[8][9] Uber Autonomous Volvo. Photos capture
in-vehicle experience. Photos by Jeremy Bass

Distance

Distance traveled in self-driving mode.

Directional Cues

Animation reflects the actual turning of the vehicle. A stop sign flashes in the middle when the car brakes.

Is this useful to the user if it is small and seems to lack visual heirachy?

Vehicle Mode

Notifies the passenger if the vehicle is in self-driving mode or being driven by the safety driver.

Uber

Vehicle passenger is riding in.

[10] Uber Autonomous Volvo. Photos capture primary user interface on the interior of the vehicle. Photos by Jeremy Bass

Speed Display

Numeric and 'fill-up' animation as speed increases. Do passengers actually need this information?

Object Detection

Objects (primarily cars) light up blue as the car detects them. Will passengers find this valuable?

This entire image is an output of the car's computer vision.

Pull Over

At any time, the user can press this button to stop the ride.

very small and the color shade is too similar to the background to stand out to the passenger. If the car starts to slow down, a stop sign would flash on the screen to signal that it was stopping. With the presence of a safety driver in the vehicle and existing physical cues from the vehicle (steering wheel), this information is not being used effectively or even necessary.

Dissecting this user interface points to the beginning of exploring how to communicate pertinent information to the passengers as well as identify some pitfalls to avoid. Yet, no one is looking at this. Currently, in the development of AVs there are few companies that are focused on the interaction design components. The majority of resources are being used for the development of hardware that lead to safe and reliable operation. Uber is partially limited by having to stick to the conventional layout of a car. There is limited development in terms of developing apps and systems required to get the vehicles on the road quickly. There are abundant research efforts focusing on communication between passengers, AVs and pedestrians; however, little of that research has been implemented.

Postponing a focus on the interaction design of AV experiences will severely

[A] Full-scale model I constructed to study layouts and interactions between users. Models (left to right): Jongsoo Kim, Christina Johnston, Maggie Coblentz

limit the adoption of AVs. Assuming that technologies reach an acceptable level of reliability, we can ignore the self-driving hardware (sensors), most exterior design elements and start to focus on how an individual will experience and use the AV. Assuming a fully autonomous vehicle, the location of information in the cabin and the experience is no longer as constrained. We can also elevate the user experience from one

of being only digital to a user experience that combines both digital and physical elements - the crux of interaction design.

One of the most effective methods for gaining insights for the design of the vehicle experience was to host improv workshops. I gave groups of people chairs and confined them to a box roughly equivalent to the size of a four-person vehicle. They were instructed to demonstrate how they expect

to best utilize an autonomous vehicle-based service. These workshops served as a great starting point to quickly learn and discover user's hesitations and expectations for riding in an AV. Immediately, it became clear that user's expected to have access to vehicle information such as navigation, speed and status. They also revealed their hesitancy for unexplained actions by the vehicle and wanted to be able to fully customize the

[B] Full-scale model I constructed to study layouts and interactions between users.

[C]

[D]

Early user research regarding interior space
and controls layout. Model left: David Kim,
Model right: Miro Kroner

[E] Autonomous vehicle, Aipaca photographed next to traditional vehicle.

interior of the vehicle to their satisfaction.

User's also expected there to be a form of artificial intelligence (AI) available on board and to retain their ability to contribute to the travelling experience. This contribution during the trip could be in the form of communicating with the vehicle via voice commands or updating route information mid-journey using an in-vehicle interface.

Combining my experience riding in Uber's self-driving taxi and my own research has led me to conclude that participant's three primary concerns with transportation generally are personal safety, comfort (privacy and spatial) and travel time.

[F]

[G]
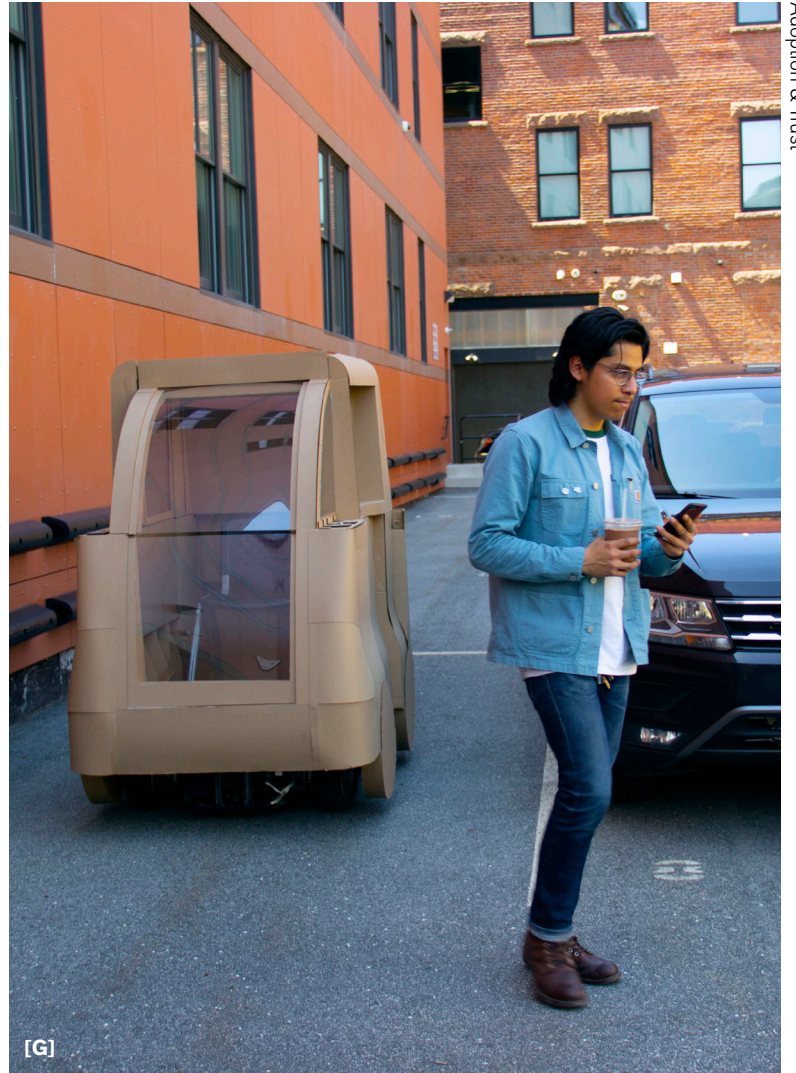
Autonomous vehicle, Aipaca. Model: Erick Medel

Vehicle Interactions.

A Robotic Framework for designing autonomous vehicle experiences.

In order to truly understand the necessary elements of an autonomous vehicle-based experience, I built my own autonomous vehicle in order to simulate the experience. I learned from the larger full-scale models I built that it was difficult to uncover these insights because the model was not moving. Initial testing confirmed previous research efforts, but revealed the need to embrace traditional interaction design principles that go beyond the digital.

To aid in the adoption of AVs, we need to address issues of personal safety, comfort and travel time using an overlap of traditional interaction design principles and behavior principles from the field of human-robot interaction (HRI). AVs performing as robots suggests a baseline of a direct exchange with an individual. An exchange is achieved when the user provides inputs into the system after an initial prompt that is then followed by an appropriate follow-up from the system.
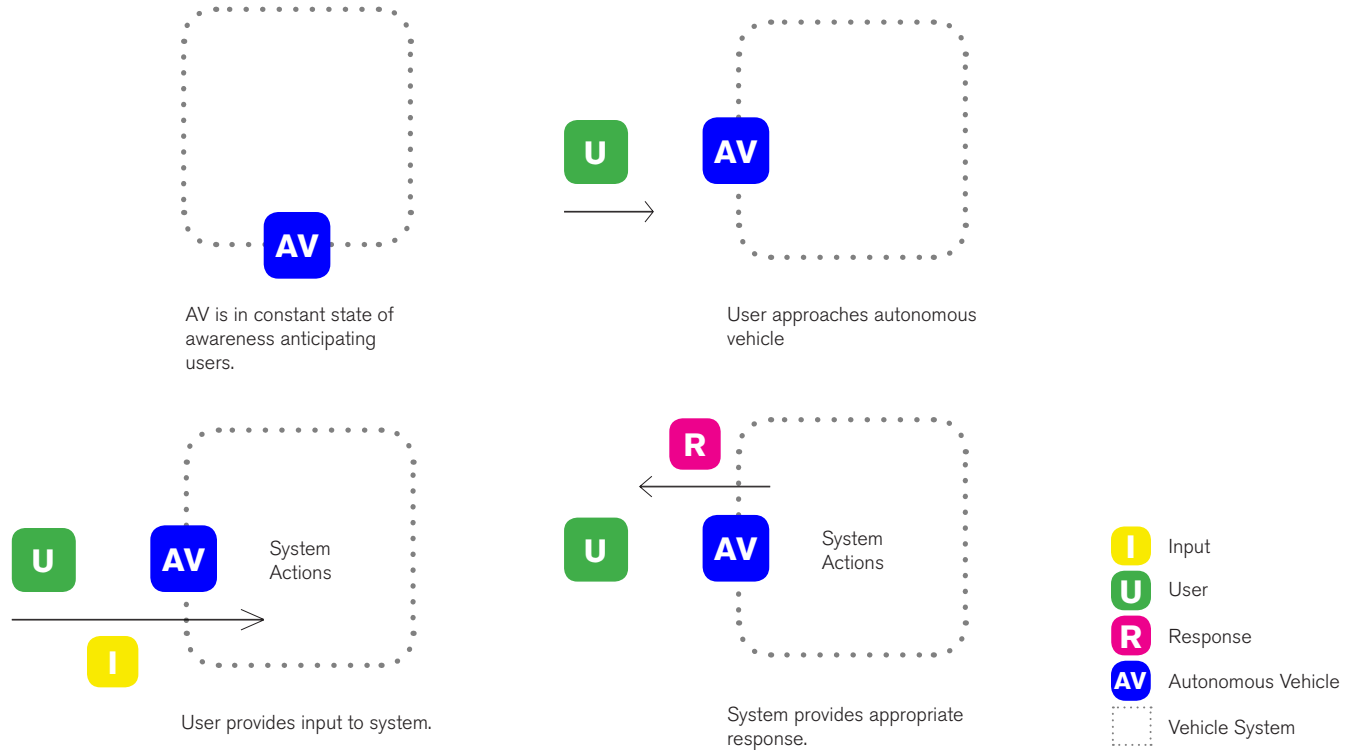
According to Industrial Designer Horatio Han, we can use a designated framework of social behaviors for designing robots.

In The Social Behavior Guide for Confused Autonomous Machines [11], Han proposes a framework in which robots are considered 'confused autonomous machines'. By designating the robot to a confused state, we can establish a set of behaviors and actions always requiring a complete interaction cycle from both parties involved. If the robot is confused, it will not complete an action without the appropriate response from the user. This will also allow for the design of a more personalized service and experience. Due to the lack of a driver or operator present in the vehicle, creating the illusion that passengers are in control of their experience will also likely lead to an increase in passenger comfort.

This 'illusion' can be created by applying adaptations of principles from the HRI field and Han's research. When designing these

AV

AV is in constant state of awareness anticipating users.

U AV

User approaches autonomous vehicle

U AV System Actions

I

User provides input to system.

R

U AV System Actions

System provides appropriate response.

I Input
U User
R Response
AV Autonomous Vehicle
Vehicle System

interactions that depict how the user will "flow" through the system, it is important to consider how and when the system (vehicle) requires input from the user and the response provided in return. Providing opportunities for the user to contribute to the experience can help achieve the perception of control. This will also allow the user to feel involved in the experience. These contributions come at moments when the process can not continue without the user's input. This system of interactions between the user and AV is made up of microinteractions. These microinteractions convey the behavior of systems and methods of communication.

They can be thought of as defining elements that dictate the flow of an interaction based on the user's actions.

In the Robotic Principles chart, I have outlined seven principles (summarized from Han and HRI) that can easily be adapted to aid designers in designing AV experiences. Naturally, the development of such disrupting technology reaches the masses in phases. Similarly, I have divided the robotic principles into three phases of integration. This project only covers phase one which includes three of the seven principles. Phase two and three speak to a system that is capable of more advanced

interactions with refined higher levels of UX. Advanced interactions will be possible once the technology is adopted. These seven robotic principles are just the beginning of a framework for designing AV experiences and do not speak to the exterior design of the vehicle.

In phase one, the principles of Reveal Acknowledgement of the User, Show Intention and Give Rationale are necessary for establishing a trustworthy AV service in the initial stages of introduction. These principles can be used to describe an overview of the user flow. This user flow is divided into three stages: onboarding,

Robot Behavior Principles

	Principle	Definition	Benefit	Not in AV
PHASE 1	Reveal Acknowledgment of the User	Must signal awareness of the user	Eliminate onboarding and offboarding confusion	AVs use safety drivers still. AV is not aware.
	Show Intention	Robot must inform user of what it will do next	Alleviate fear, confusion and increase adoption	AVs are modeled after public transit services
	Give Rationale	Inform user why it is performing its actions	Heightened awareness and trust	Changes in navigation or driving behavior are not explained
PHASE 2	Communicate Anticipation	Communicate to users what it is expecting	Efficiency, prevent user confusion and errors	Passive display of information, not actual communication
	Facilitate Augmentation	Robots must augment or enhance the human, not create a dependency	Aid to establish cognizant community that respects the service	Lack of interactions overall
PHASE 3	Embody gestures	Embody gestures familiar to users that suggest actions	Aid in higher adoption rate, comfort	No use of gestures beyond a virtual steering wheel
	Instill Common ground	Both parties must have mutual knowledge of each other's capabilities	Adaptable to diverse groups of users	No adaptation of service

Application

Sensors corresponding to light or
sound that respond to user

Vehicle status screen with
directional cues or app push
notifications

Passenger receives alerts
with prescribed reasons

Visual and auditory cues to guide
users

AV can provide social motivators
and suggest acceptable service
behaviors

Incorporate gestures from traditional
cars

Catered service to diverse user
group regardless of age, abilities
or background

enroute and arrival.

Han describes the principle of acknowledgement as being crucial to initiating interactions between the user and the 'robot'. The vehicle must always signal its awareness of the user's presence. The vehicle 'acknowledges' the user's presence through the use of light, sound and visual cues. This is especially important in the onboarding process where user's will have to approach vehicles and follow commands before beginning their journey.

After the user requests a vehicle via an app or kiosk, the vehicle's exterior lights will change to a solid color to signal its 'in-transit'

status. Once the vehicle pulls up to the curb, and the user approaches, the exterior lights once again change to reflect that the vehicle is aware of the user approaching and that it is 'hired' (this light can also be coded to reflect vehicle function). The handle on the vehicle glows to guide the user further and as the door is opened, interior lights illuminate.

Once seated, the vehicle's main interface lights up to welcome the user. Immediately following the welcome screen is a reminder to buckle up. To reinforce this action required by the user, the light surrounding the vehicle interface glows orange. Orange signifies that a response is needed or that the

user's attention is required. The user is also reminded by the familiar sound of seat-belt warnings in traditional cars. Finally, the user is presented with a screen requesting a confirmation that they are ready to start the trip (orange glow). The user is able to confirm by pressing the button located next to the seat. Once confirmed, a green glow appears around the screen.

In stage two (enroute), the vehicle's intention is important to communicate to the user as the journey has started. At the beginning of the trip, route details and intended course of action are flashed onto the screen awaiting the user's final confirmation. Throughout the trip, if the vehicle is turning or changing lanes, it will provide the user with directional cues via the vehicle interface. The corresponding direction (left or right) will illuminate along the edges of the vehicle interface screen. Both directional cues flash (like a traditional hazard signal) when the user is getting in or out of the vehicle. When the vehicle is slowing down to a stop, both directional cue lights glow red with an increasing intensity until reaching a complete stop. Once stopped, the glow remains until taking off again. This temporary static state enables the user to quickly assess the vehicle's state of motion at all times.
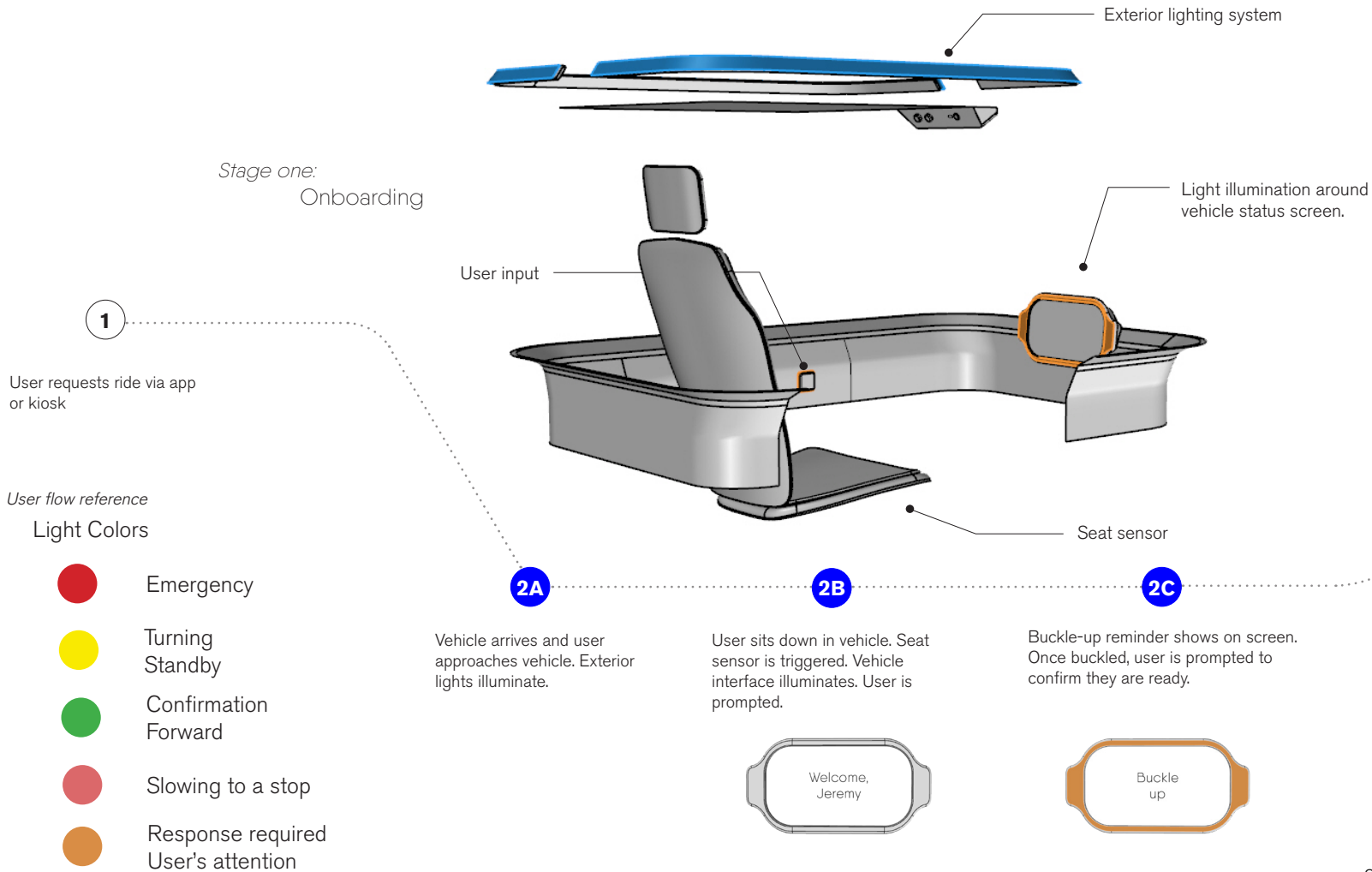
User Flow

The user flow is divided into three phases: onboarding, enroute and arrival.

Robotic Principle #1:
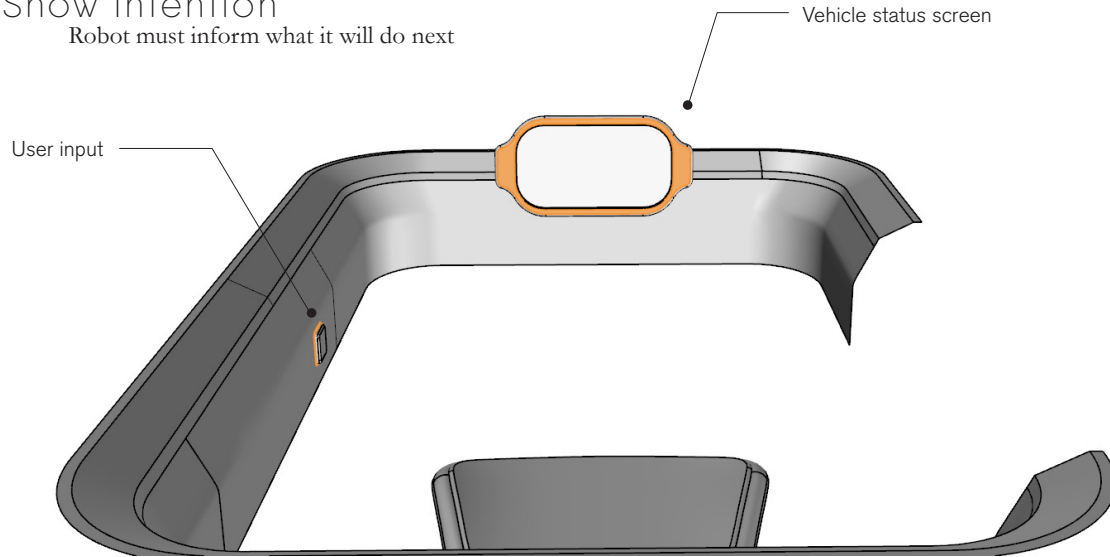
Present Acknowledgement of the User

Robot must signal its awareness of the user's presence.

Exterior lighting system

Stage one:
Onboarding

Light illumination around vehicle status screen.

User input

1

User requests ride via app or kiosk

Seat sensor

User flow reference

Light Colors

- 🔴 Emergency
- 🟡 Turning
  Standby
- 🟢 Confirmation
  Forward
- 🔴 Slowing to a stop
- 🟠 Response required
  User's attention

2A

Vehicle arrives and user approaches vehicle. Exterior lights illuminate.

2B

User sits down in vehicle. Seat sensor is triggered. Vehicle interface illuminates. User is prompted.

Welcome, Jeremy

2C

Buckle-up reminder shows on screen. Once buckled, user is prompted to confirm they are ready.

Buckle up

Show Intention
Robot must inform what it will do next

Vehicle status screen

User input

Let's
go

3A

User is prompted with final confirmation to start trip. User confirms with button next to seat.

Tallulah's Taqueria
146 Ives Street

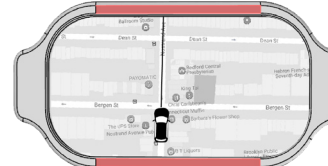Dist. 3.2 miles   Est. Arrival 3:36pm

3B

Vehicle displays destination and travel information. Solid green signifies the vehicle is moving forward.

Stage two:
enroute
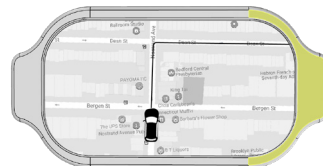
3C

During the trip, the vehicle signals directional cues to the user before turning or changing lanes.

3D

The vehicle informs the user when it is slowing down to a stop.
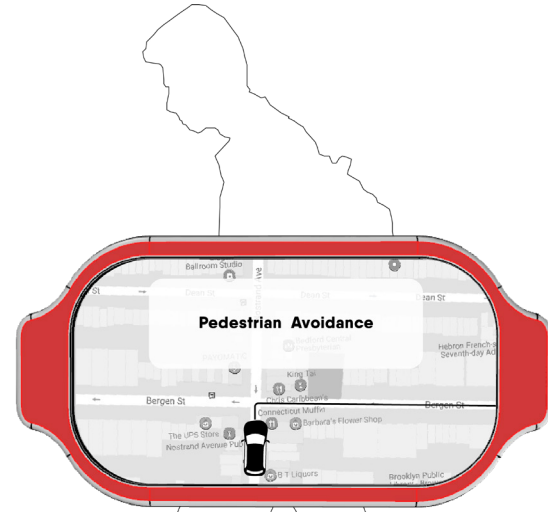
Robotic Principle #3:

Give Rationale
Inform user why it is performing its actions

4A

Vehicle provides user with route updates if original navigation route is modified.

4B

Vehicle provides user with reason for any sudden stopping or unusual driving behavior

One of the challenges that AV based services will face is the user's reaction when the vehicle does not perform in the way that the user expects it to. These expectations are based on the user's own abilities, experience with driving or just their subjective thoughts based on the environmental context. To help alleviate this potential issue, we can use the principle of Give Rationale. Give Rationale states that the vehicle must inform the user why it is performing its actions. If the vehicle is driving along and suddenly modifies the route based on traffic congestion or an accident, it will notify the user by illuminating the edges of the vehicle interface screen in orange and flashing a text-based update on the screen. The vehicle performs the same in the event of unusual driving. If the vehicle makes a sudden stop, the edges of the vehicle interface screen illuminate in red.

5

5A

5B

6

User exits vehicle

You've arrived

Tallulah's Taqueria
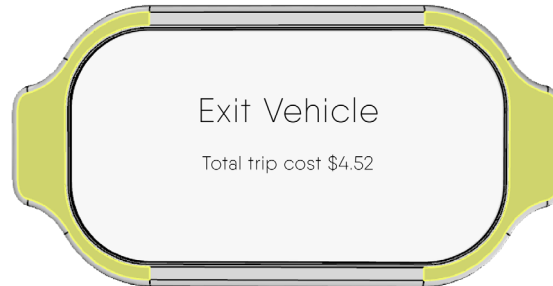146 Ives Street

Exit Vehicle

Total trip cost $4.52

Vehicle has arrived at destination.
Vehicle safely pulls over and puts
hazard lights on.

User is asked to exit vehicle and is
provided with a total trip cost.

Conclusion

Summary and next steps

The introduction of AVs as a transportation alternative and addition to the existing mobility landscape provides us with the opportunity to rethink our experiences with transit and cities. AVs will free up time normally spent sitting in the driver's seat that can be translated to other activities. Even though this sounds idyllic to most, it will still be difficult to convince people to adopt and trust a vehicle that they can not directly control themselves.

This is where I believe that designers can and should intervene. We must eliminate as much passenger confusion and hesitation as possible for adoption to occur. As previously stated, designers should approach the design of user experiences for autonomous vehicle based services as if the vehicles are robots. By doing so, we can 'unlearn' traditional car design conventions and explore new levels of interactions between passengers and these shuttling robots. This book is intended to serve as a call to action to get designers involved and to provide a viable starting point. Through the adoption of ideas and principles from the field of human-robot interaction, we can redefine mobility suited for a near future. This also serves as a critical starting point for exploring the design of the system in which these robots will operate.

I arrived at this 'approach' (robots, not cars) through my own research with users. Even though disrupting forms of mobility currently rely heavily on a smartphone app and are somewhat successful, my research highlighted the fact that users desired more support. We all get nervous when riding in the back of an Uber. They were highly concerned about the vehicle's status and how they would possibly understand the behaviors of new AV based services. They expressed a desire for the vehicle to communicate to them, rather than ride in a passive system.

I strongly believe that with this fresh approach, we can also reconsider the system

overall. In an ideal system, AVs will serve as supplants to existing public transit. They will be available to all, and help us work towards a system based on equitable transit goals. In order to support existing public transit, I do not believe that AVs should be available for individual purchase. Allowing the individual sale of AVs will increase traffic congestion and introduce more issues than they will solve, such as: inconsistency in tech among manufacturers, hackers, maintenance, regulation disparities and many more.

Even though I have only suggested seven principles and given specific examples of three, the possibilities of applications are lengthy. Having established a new framework to design from, the next stages of this project would be to conduct further research in the field of HRI to find other applicable robot behavior principles. Ultimately, this framework will contain a set of principles that are deemed the minimum for designing AV experiences for both the interior and exterior. After establishing this framework, one can move onto designing the nuances of the user experience (screens, app, controls). With the properly designed user experiences, designers will be able to transition to re-imagining the physical interior of AVs.

Bibliography

[1] FXFOWLE & Sam Schwartz Engineering. "Public Square". *Archdaily,* Archdaily News, 22 July. 2016, https://www.archdaily.com/875787/the-driverless-future-challenges-winning-entry-uses-plug-and-play-system-to-reclaim-public-space-for-pedestrians?ad_medium=widget&ad_name=navigation-prev

[2] Volkswagen. "Sedric". *Cnet*, Chris Paukert, Road Show by Cnet, 13 March. 2018, https://www.cnet.com/roadshow/news/vw-confirms-16-ev-plants-by-2022-plans-to-build-sedric-pod-concept/

[3] Navya. "Navya Arma". *Stuffi*, Vincent Bouvier, Stuffi, 16 Feb. 2016, https://www.stuffi.fr/on-a-teste-le-vehicule-autonome-francais-navya/

[4] Google. "self-driving car prototype". *The Verge,* Sam Byford, The Verge, 15 May. 2015, https://www.theverge.com/2015/5/15/8610667/google-self-driving-car-public-testing

[5] Local Motors. "Olli Autonomous Bus". *Car Design News*, Farah Alkhalisi, Car Design News, 5 Aug. 2016, http://cardesignnews.com/articles/car-design-blog/2016/08/reading-week-5-august-2016

[6] Bomey, Nathan. "U.S. Auto Industry's Record Sales Streak Snapped in 2017." USA Today, 3 Jan. 2018, https://www.usatoday.com/story/money/cars/2018/01/03/u-s-auto-sales-record-streak-likely-snapped-2017/999182001/.

[7] Toyota. "Toyota Rav4 Limited Interior". *the truth about cars*, Alex L Dykes, The Truth about Cars, 2016, http://www.thetruthaboutcars.com/2016/02/2016-toyota-rav4-review-soft-soft-roader/2016-toyota-rav4-limited-interior-008/

[8][9] Photos from personal trip to visit the Uber office in Pittsburgh, PA. Photos detail the in-vehicle experience and are by Jeremy Bass.

[10] Uber Autonomous Volvo. Photos capture primary user interface on the interior of the vehicle. Photos by Jeremy Bass

[11] Han, Yuxin. The Social Behavior Guide for Confused Autonomous Machines. Self-published, 2016.

Cover Photo:

[12] Unknown. "A laser and a Raspberry Pi can disable a self-driving car." *Extreme Tech*, John Hewitt, Extreme Tech, 8 September, 2015, https://www.extremetech.com/extreme/213517-a-laser-and-a-raspberry-pi-can-disable-a-self-driving-car

Personal project process phots:

[A] Initial full-scale model built in the fall semester (2017). Nicknamed the "Gondola." Models: Jongsoo Kim, Christina Johnston and Maggie Coblentz.

[B] Full view of full-scale model built in the fall semester (2017).

[C] Process photo of working autonomous vehicle, Aipaca. Model: David Kim.

[D] Process photo of working autonomous vehicle, Aipaca. Model: Miro Kroner.

[E] Aipaca photographed outside next to a traditional vehicle for scale comparison.

[F] Passenger in Aipaca. Model: Erick Medel.

[G] Passenger leaving Aipaca. Model: Erick Medel.

A thesis submitted in partial fulfillment of the requirements for the degree Master of Industrial Design in the Department of Industrial Design of the Rhode Island School of Design

_____

Michael Lye
Associate Professor, Industrial Design
Rhode Island School of Design

_____

Jerome Arul
Adjunct Faculty, Industrial Design
Rhode Island School of Design

_____

Pierre Beaudreau
Designer & Urban Strategist
Optimus Ride