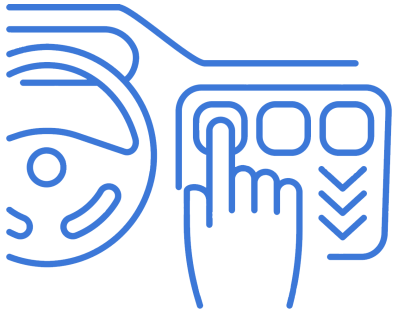


HCI 594 Final Report:

Tactile Vehicle Interface Design

November 22, 2022

Abstract

Recent developments in automobile software development and design have led to increased features available within car infotainment systems. These features improve the driver's experience of owning a car but may not be advantageous for safe driving. As vehicle UIs have shifted to all-touchscreen designs with little to no buttons, there is a significant increase in risk of distracted driving due to the visual input required to operate the UI. To mitigate this issue, we aimed to (1) generate an automotive UI that prioritizes safety by introducing tactile buttons, (2) reduce cognitive load by removing features that are unnecessary or too complex, and (3) prioritize most used features to be most easily accessible within the UI.

To help us better understand the current landscape of vehicle UI use, we began with a thorough literature review, competitive review, card sort, and contextual inquiry with 5 users which indicated the best solution would have a balance of buttons and touchscreen controls to mitigate driver distraction. We then conducted three prototyping rounds, which culminated into a physical in-vehicle prototype with a touchscreen interface and physical buttons. We conducted first-click testing with 5 users and usability testing with 4 users, which demonstrated low levels of driver distraction and high learnability of the touchscreen-button UI controls. We also propose future work to further improve the usability of the new UI.

Introduction

Motivation for Project Product

How can we design an automotive infotainment interface that **prioritizes safety and usability** while integrating sought after **aesthetics and touch features**?

Design for Safety

Evaluate Bimodal UI
(buttons + touch)

Reduce Cognitive Load

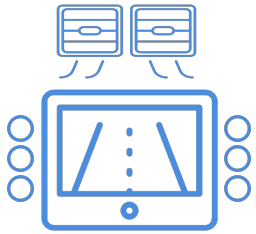
Consider Aesthetics vs. Usability

Prioritize & Sort UI Elements

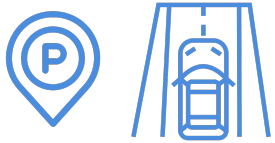
Target Demographic & Context

Who & what are we designing for?

Modern Car Owners
Model Year 2016 & Newer



Dashboard Infotainment System



While Parked or Driving

Literature Review: **Safety & Distraction**

Cognitive Task-Based Distraction

Dual task performance *(e.g. driving and talking on hands-free cell phone)* significantly reduces reaction time and perceptual encoding (Strayer et al., 2011)

Visual & Cognitive Distraction

Visual distraction impairs driving performance more than cognitive distraction. (Liang & Lee, 2010)

Automotive Display Impact to Visual Performance

- Response time to identify visual targets significantly decreased in presence of simulated automotive display.
- A driver traveling 65mph looking at an automotive display for 0.24s = reduced visibility for 22.88 ft (1.6 car lengths) (Lovell et al., 2021)

Literature Review: Emotional State

Effects of Emotional State on Driving

Yerkes-Dodson Law: Task performance is best with medium arousal state (vs. low or high) and medium to high valence (positive emotion).
(Braun et al., 2021)

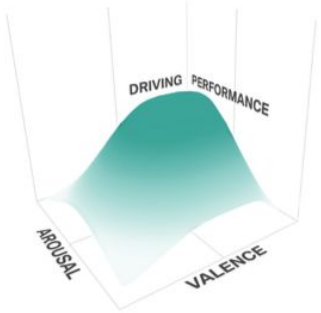


Fig. 1. Model of driving performance based on valence and arousal as proposed by Cai & Lin [21]. Best performance is expected at medium arousal, derived from the law of Yerkes & Dodson [118].

Fig. 2. Emotional driver taxonomy on grounds of the circumplex model by Russell [90]. Assumptions of a safe driving state at medium arousal and high valence predominate in the literature [12].

Triggers of Emotions While Driving

- **Negative:** Other drivers, environment, near accidents, **unsatisfactory interactions with in-car UI**, time pressure, verbal interactions
- **Positive:** Nice surroundings, positive interactions with passengers, car performance, general enjoyment
(Braun et al., 2021)

Literature Review: Emotional Regulation

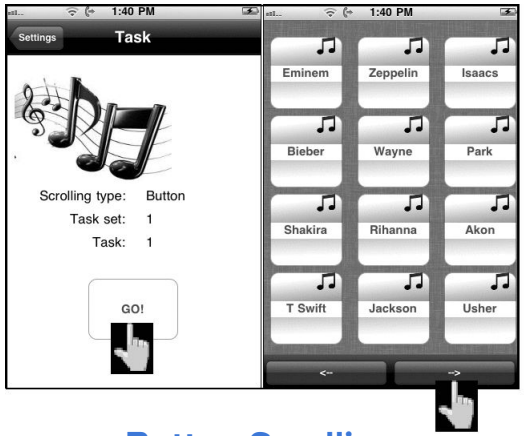
Vehicle Emotion Regulation Approaches (Braun et al., 2021)

- **Adaptive music:** happy music decreases driving performance, sad music increases calmness and driving performance
- **Ambient light:** Blue light decreased anger and blood pressure, but ambient light changes can also be alarming or distracting
- **Empathetic speech:** Improves driver focus and reduces negative emotional state
- **Reappraisal:** Aim to illuminate frustrating situations in a positive light
- **Relaxation techniques:** Guided slow breathing to calm arousal or fast breathing to increase alertness.
- **Emotional state feedback:** Direct feedback regarding emotional state has little value for emotion regulation and may clutter visual field
- **Temperature control:** Cool air for decreasing fatigue and increasing alertness to improve driving activity

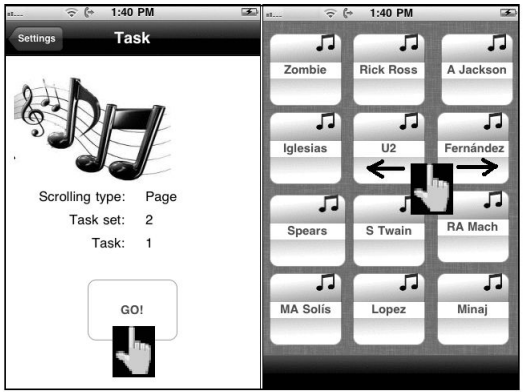
Literature Review: Kinetics

Automotive UI Scrolling Methods (Kujala, 2013)

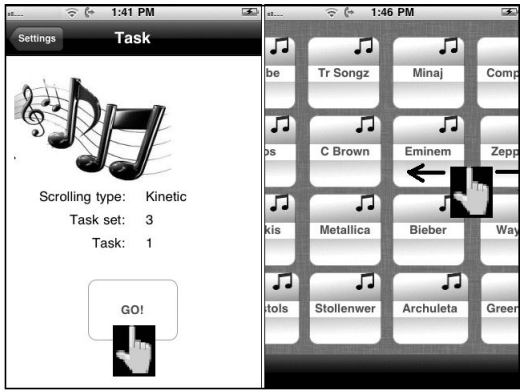
- **Kinetic scrolling:** Decreases visual sampling efficiency and increased visual load
- **Button scrolling:** Subjectively preferred, but not better on any objective measures
- **Swiping:** Better facilitates resuming visual search following an interruption, less severe distraction effects



Button Scrolling



Swiping



Kinetic Scrolling

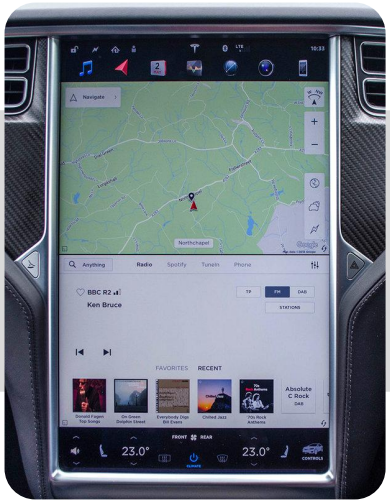
Literature Review: Kinetics

Haptic Feedback in Automotive UIs

- Decrease driver distraction by providing tactile feedback and eyes-free control (Klein, 2022)
- Increase feelings of “real-world” interaction with digital interfaces (more sliding, less tapping, multiple zones of interaction) (Klein, 2022)
- Haptic feedback reduces visual load and glance time to ensure successful action completed (Pitts et al., 2011)

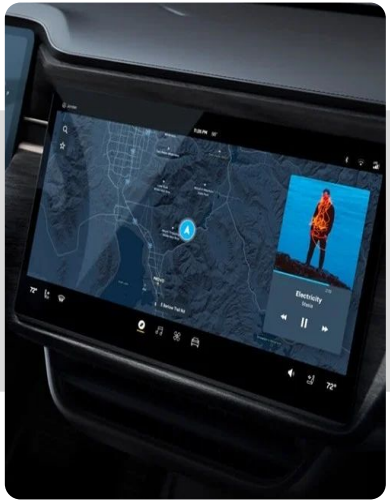
Results: Competitive Review

Fully Touch



Tesla Model X

Fully Touch



Rivian R1T

Touch + Buttons

Volvo S60

Buttons + Mousepad

Acura RDX

Electric Vehicle Companies

OEM Companies

Competitive Review

Audited Top 8 Vehicle Brands

- Identified top features in popular vehicles that have touchscreen interfaces
- Included most common features in card sorting
- Included “luxury” features to determine nice-to-haves vs. need-to-haves

	Tesla	Honda	Toyota	Jeep	Ford	BMW	Hyundai	Nissan
Setup								
	17" touchscreen with left-right tilt	1x 7- or 8-inch touchscreen	Mostly 6.1- or 7-inch touchscreens, up to 9in, mostly landscape mode	7- and 8.4-inch touchscreens, mostly landscape mode	otherwise 6.5- or 8-inch touchscreens, newe models have 10 inch portrait style screens	most are 12 inch touchscreens	7- or 8-inch touchscreens	5- is standard, 7-inch touchscreen with navigation is optional
	portrait or landscape	Tile layout	Tile layout	Uses UConnect (vehicle platform that is built into Chrysler, Dodge, Jeep, Wagoneer, Ram and FIAT)	base versions are non touchscreen.	basic features are included, all BMW models can be upgraded to an infotainment system called iDrive		many come with a very basic AM/FM/CD system with few added features besides Bluetooth and auxiliary connectivity
	lacks all physical controls	lack of physical volume and tuning buttons	has some physical controls	offers many redundant physical buttons bc of issues w/ UConnect	basic functions are physical buttons / controls	newer models offer limited gesture-recognition ability, ie a twirled finger for volume Most models are controlled using a rotary jog dial on the center console		Leaf's infotainment system is available for newer models
Features								
Cabin heating	X	X	X	X	X	X	X	X
heated seats and windows	X	Some	Some	Some	Some	X	Some	Some
Air conditioning	X	X	X	X	X	X	X	X
Individual climate control	X	?	?	Some	Add on	?	?	?
Lane departure warnings	X	?	?	X	?	?	?	?
Cruise control	X	X	X	X	X	X	X	X
Rear (trunk) hatch switch	X	X	X	X	X	X	X	X
Sound/volume controls	X	X	X	X	X	X	X	X
Headlight switch	X	X	X	X	X	X	X	X
Reverse camera	X	X	X	Add on	?	?	?	X
radio channels	X	X	X	X	X	X	X	X
Car lighting	X	X	X	X	X	X	X	X
Contacts	X		X	X	X	X	X	X
Music	X	X	X	?	X	X	X	X
Audiobooks	X	?	?	?	?	?	?	?
Voice assistant	X	?	?	X	X	Alexa-like features	X	Limited (Google Assistant voice)
streaming services	X	Through phone	Through phone	?	?	X	?	Through phone
Gaming	X	?	?	?	?	?	?	?
Podcasts	X	?	X	?	?	?	?	X
Navigation	X	X	X	?	Add on	You can "write" letters and numbers atop the controller in certain models	X	X
Phone connections	X	X	X	X	X	X	X	X
Apps	X	Some	X	Limited	X	?	X	X
Apple CarPlay	X	Some	Limited	Limited	Add on	Add on	X	Limited
Android Auto	X	Some	Limited	Limited	Add on	No	X	Limited
Wi-Fi hot spot	X	Some	Some	Add on	Newest only	X	X	Some
Blind spot warning	X	X	X	Add on	?	X	?	X
Bluetooth	X	X	X	X	X	X	X	X
USB port	X	X	X	X	X	X	X	X
AUX port	No	X	X	X	X	X	X	X
SiriusXM traffic information	No	X	X	Add on	Add on	?	Add on	X

Project Guiding Principles

What makes us better than the competition?

Improved Reach Zones & Visibility

Putting the most important features within easy reach

Shift Design Focus from Futuristic to Usable

Less focus on being iPad-esque, more focus on solving user problems and empowering users to control their vehicle without adding cognitive load

Improve Affordances

Re-introduce tactile interactions with affordances with touch, haptic feedback, and sound to require less visual input

Simplify Interactions

Reduce complex interactions that require too many steps and visual attention

Project Goals

Goals & Measures

1.

Generate an automotive UI that prioritizes safety through use of tactile buttons

Measures - Usability Testing:

- Frequency & time spent looking at interface
- Task success rate in absence of visual focus

2.

Reduce cognitive load by removing features that are too complex or unnecessary

Measures:

- **Usability Testing -** Reduction of time on task
- **Hybrid card sort** - Cards categorized as unneeded

3.

Prioritize of most commonly used features to be most easily accessible within interface

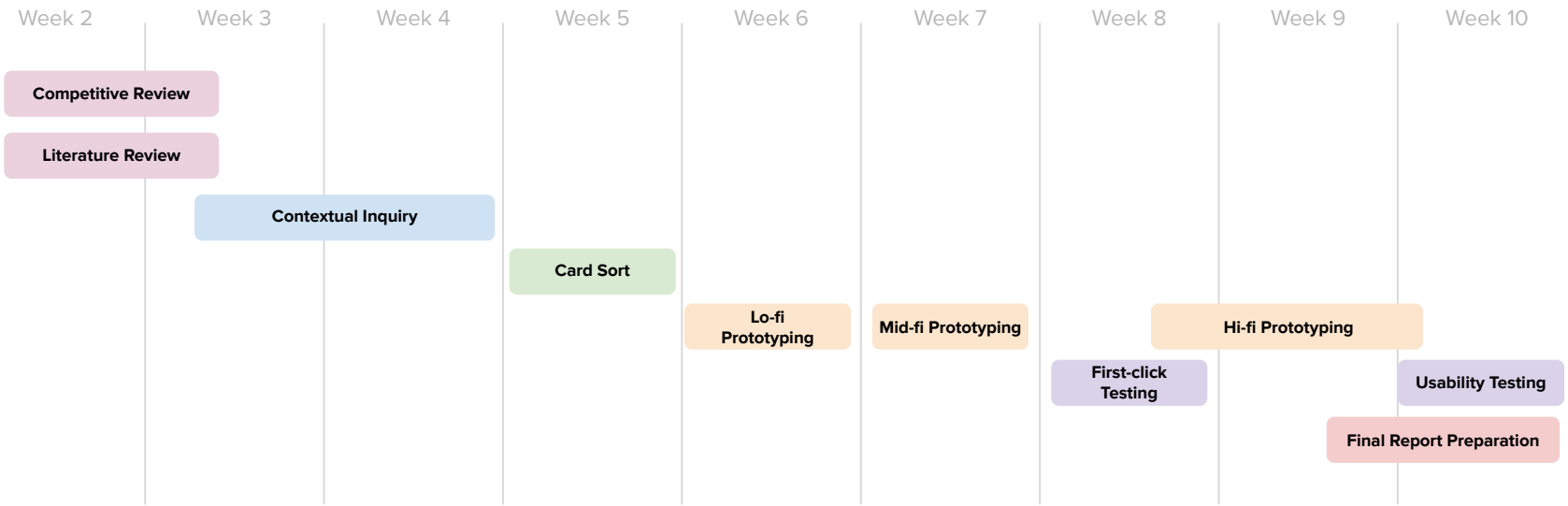
Measures:

- **Hybrid card sort -** Frequency of cards
- **Hybrid card sort -** How cards are organized
- **Contextual inquiry -** Frequency of feature use

These goals & measures remained consistent throughout our project.

Methods

Roadmap


Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Competitive Review
Literature Review
Contextual Inquiry
Card Sort
Lo-fi Prototyping
Mid-fi Prototyping
Hi-fi Prototyping
First-click Testing
Usability Testing
Final Report Preparation

Methods: Research

Competitive Review

- Studied feature sets of top 8 automotive brands in US
- Analyzed how the infotainment interfaces of existing automobile companies address user needs
- Considered usability and accessibility standards maintained by existing companies
- Allowed us to design something that stands out from what is already out in the competitive space

Literature Review

- Gained an academic perspective to substantiate our rationale behind feature implementation
- Aided in articulating our research based on peer-reviewed studies of ergonomics and automobile interface design

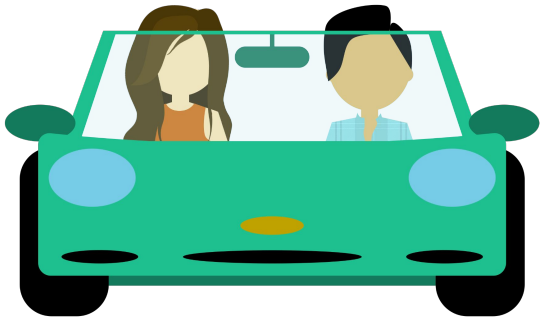
Methods: User Research

Contextual Inquiry

- 5 participants
- Participants owned these vehicles

2020 Ford Transit
2017 Honda Civic
2016 Toyota RAV4
2019 Hyundai Accent
2019 Tesla Model 3

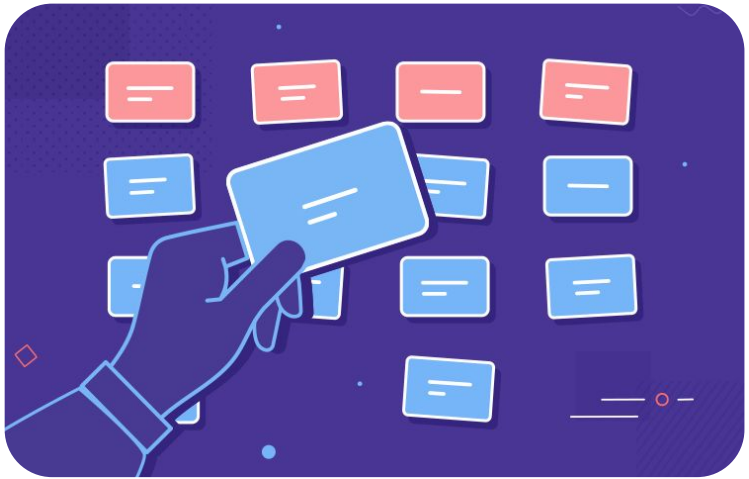
- 30-minute scripted, structured sessions
- Participants asked to complete scenario-based tasks while parked or moving through an empty parking lot
    - Navigation
    - Calls
    - Music
    - Climate control
    - Backup camera
    - Voice recognition features
- Discovered how people interact with their vehicle infotainment system in their natural context. We also learned about likes and potential pain points with existing infotainment interfaces



Methods: User Research

Hybrid Card Sort

- **46 participants,** filtered down to **28 participants** with usable data (owned a car with a touchscreen)
- 34 cards & 9 preset categories (with the option to add more)
- Data collection tool: Optimal Workshop - **OptimalSort**
- Data analysis tool: **OptimalSort & FigJam**
- Using our competitive analysis and contextual inquiry results, we drafted a content inventory for our interface (see Supplemental Materials)
- We conducted a hybrid card sort to allow users to drop cards into predefined categories or create their own categories
- To determine what features may be unnecessary, we also had an “I wouldn’t use this” category
- Helped us understand where users expect to find features within the navigation of their infotainment systems. Identified features that users find unnecessary to remove in the new design



Methods: Prototyping + Testing

Lo-fi Prototyping

- Completed in FigJam
- Rapidly iterated through design ideas by limiting interactive elements and aesthetics
- Limited to our group members only based on results from contextual inquiry, competitive analysis, and card sort data

Mid-fi Prototyping

- Completed in Figma
- Created a simple prototype of the interaction design basics to use in first-click testing
- Prioritized most commonly used features from user research phases

Methods: First-click testing

Method

- 5 participants
- Testing platform: Chalkmark on Optimal Workshop
- Moderated testing performed using driving sim setup + iPad as touchscreen UI
- Only touchscreen UI was tested - not physical buttons
- 7 scenario-based tasks randomly displayed to each participant

Methods: First-click testing

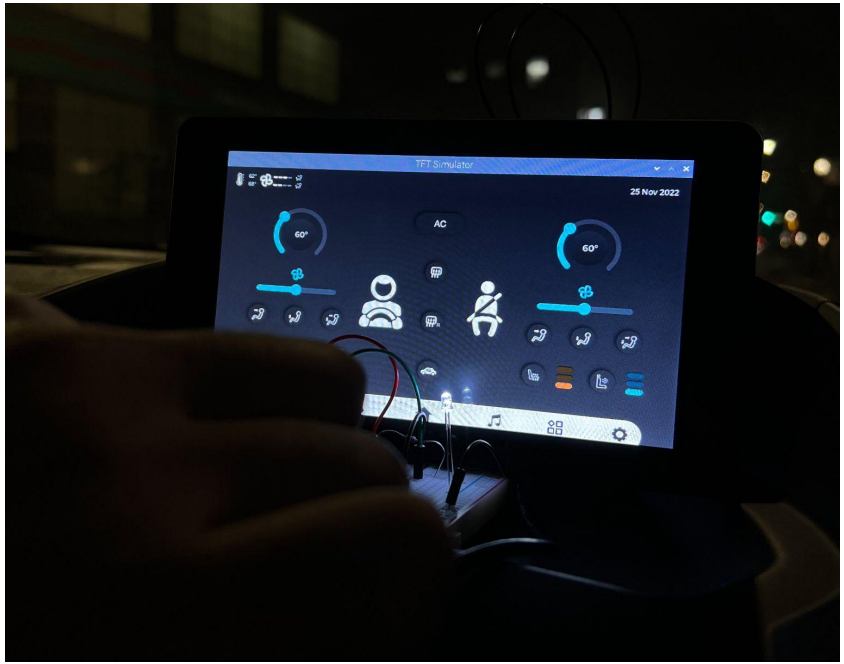
Tasks

1. Imagine you are driving and want to lower the fan speed of your air conditioning. Where would you do so?
2. Imagine you are driving and want to listen to the audiobook you have been listening to all week. Where would you do so?
3. Imagine you are driving home from an unfamiliar location. Where would you tap to get directions?
4. Imagine you are driving and want to hear a text message you just received. How would you do so?
5. Imagine you are driving and want to listen to the next song in your playlist. How would you do so?
6. Imagine you are driving home from work while your partner is at the grocery store. You just hung up with them, but you realized you forgot to tell them to buy milk. How would you call them back?
7. *[You are not driving for this task.]* Imagine you have just created a new playlist on your favorite music app. You want to set up a shortcut to that playlist on your car screen. How would you do so?

Physical Setup: iPad + YouTube Driving Simulator

YouTube Driving Simulator Link

Methods: Hi-fi Prototyping



Hi-fi Prototyping

- Created a physical prototype with real buttons and a touch screen to mimic a real automotive interface
- Prototyped some buttons to control elements on the screen and some to send signals to LED. The idea was to see if the user can accurately do it.
- The steering wheel already had button controls for navigation
- Measured quality of design through additional usability testing in an in-vehicle context to understand overall performance and usability
- Results were compared with the second attempt to assess learnability and improvement in performance

Methods: **Usability testing**

A usability test was conducted to study the participants' driving performance from a **small-scale multi-factor analysis** perspective.

The factors included:

- Button pressing accuracy
- Response time to signs
- Smooth braking
- Straight driving path

Participants were assigned **one point for every positive driving observation** (based on the above metrics) during each scenario prompt. Participants could score a perfect 140 points by completing tasks with no distraction from driving.

Based on the slow response times in our first-click testing, **we conducted each usability test twice per participant to assess learnability of the UI and button layout.**

Results

Results: Contextual Inquiry

Navigation

- 3 participants set navigation and made edits **using their phones**, while 2 **used their car touchscreens**
- 3 participants **pulled over to edit** navigation settings, 2 participants **slowed down but continued moving**

Calls

- All participants initiated and managed calls **using their vehicle**
- 3 used **steering wheel buttons**, 2 used **touch UI**
- All participants managed their calls **while driving**

Music

- 1 participant used **phone** to set music, 1 participant used **Spotify Car Thing UI**, 3 participants used **vehicle touchscreen UI** in combination with **steering wheel buttons**
- All participants managed their music **while driving**

Results: Contextual Inquiry

Climate Control

- 4 participants used **physical buttons** to change climate control, 1 used **touchscreen UI**
- All participants managed climate settings **while driving**

Backup Camera Use

- All participants **relied on backup camera** for reverse driving

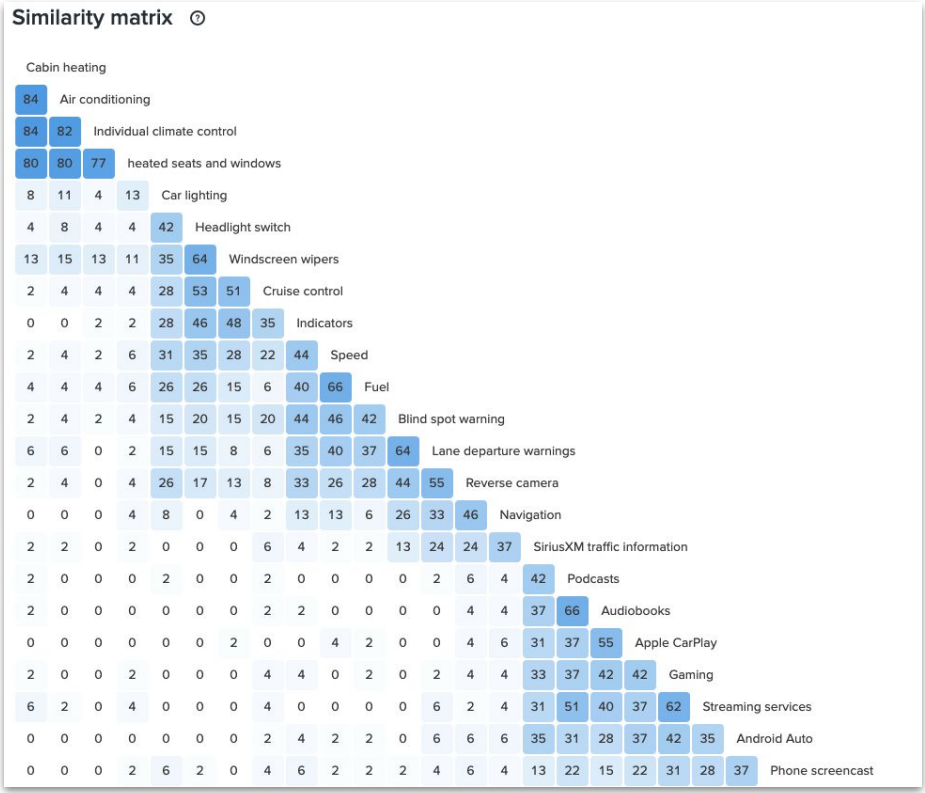
Voice Recognition

- Only 1 participant used voice recognition features (for music changes)
- Other participants noted **lagginess**, **lack of awareness** their car had voice recognition, or issues due to **language barriers**

Results: Card sort

Mixed Results

- Although we included screening questions, it was clear that **many participants didn't understand the features**
- We relied heavily on the similarity matrix to **combine categories or cards that appeared redundant**
- We used the results to inform which features weren't clearly understood/important to users by thinking through intended use

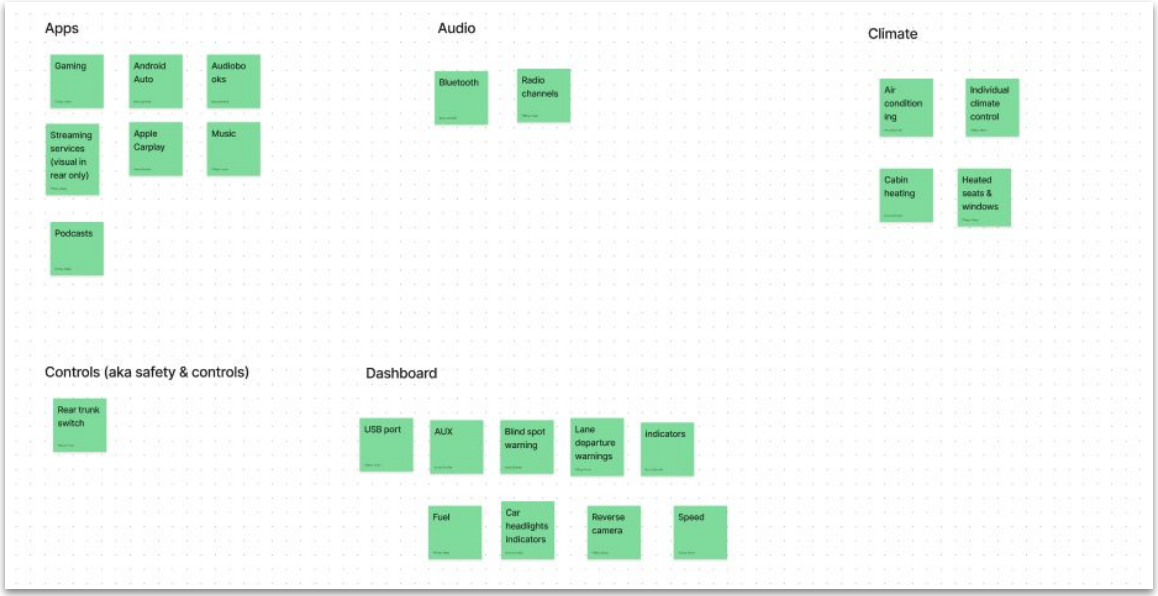


Results: Card sort

Category-based Sort

- We used the results and did a brainstorming session to reduce complexity that confused users in the card sorting exercise
- These new categories formed the top-level and second level nav in our lo-fi prototypes

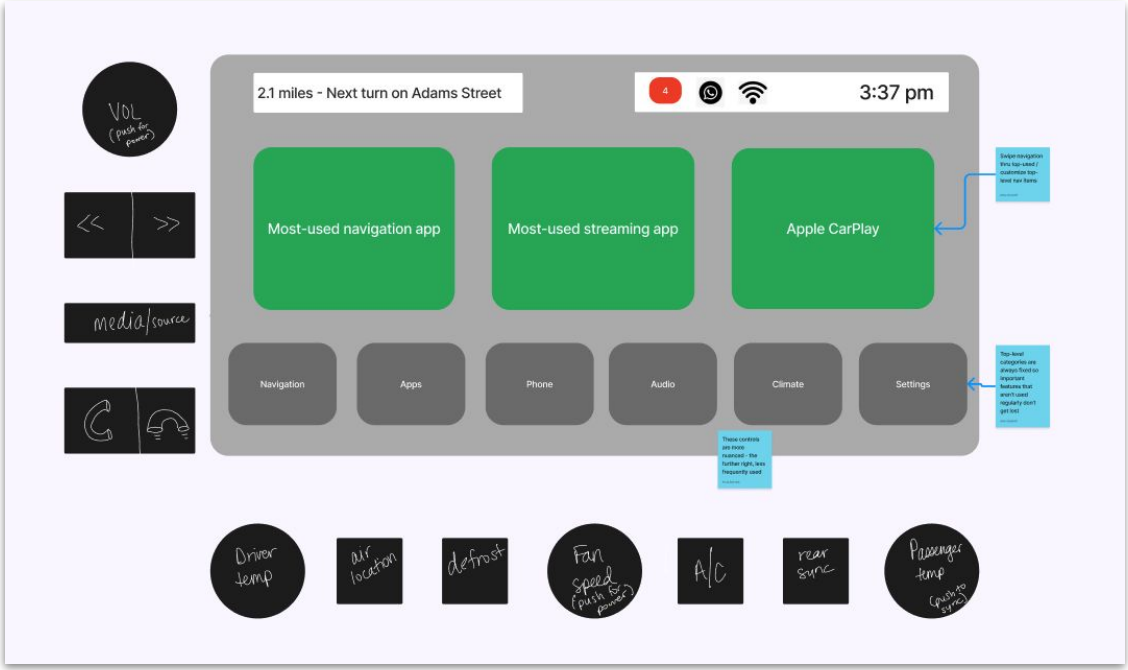
New categories



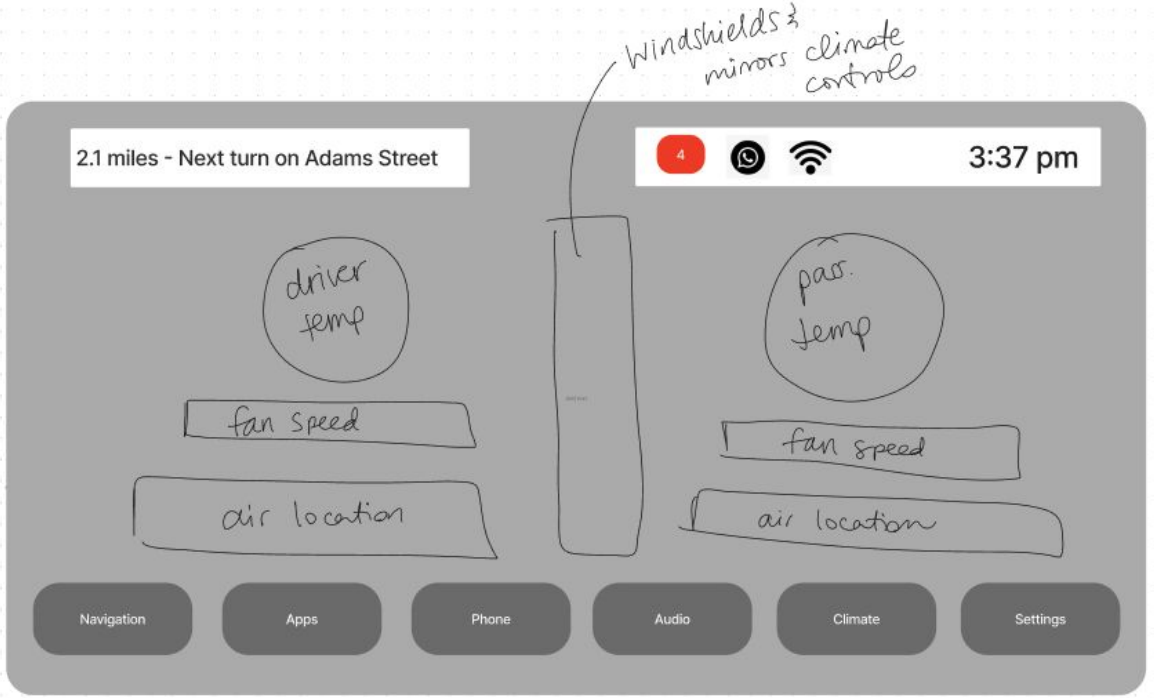
Lo-fi prototyping

Home Screen IA

- We used lo-fi prototypes to build out the rough IA for our homescreen prioritize key features
- Our lo-fi prototype includes a first draft of the **tactile buttons** adjacent to the touch screen **based on the most commonly used features from our contextual inquiries**



Lo-fi prototyping

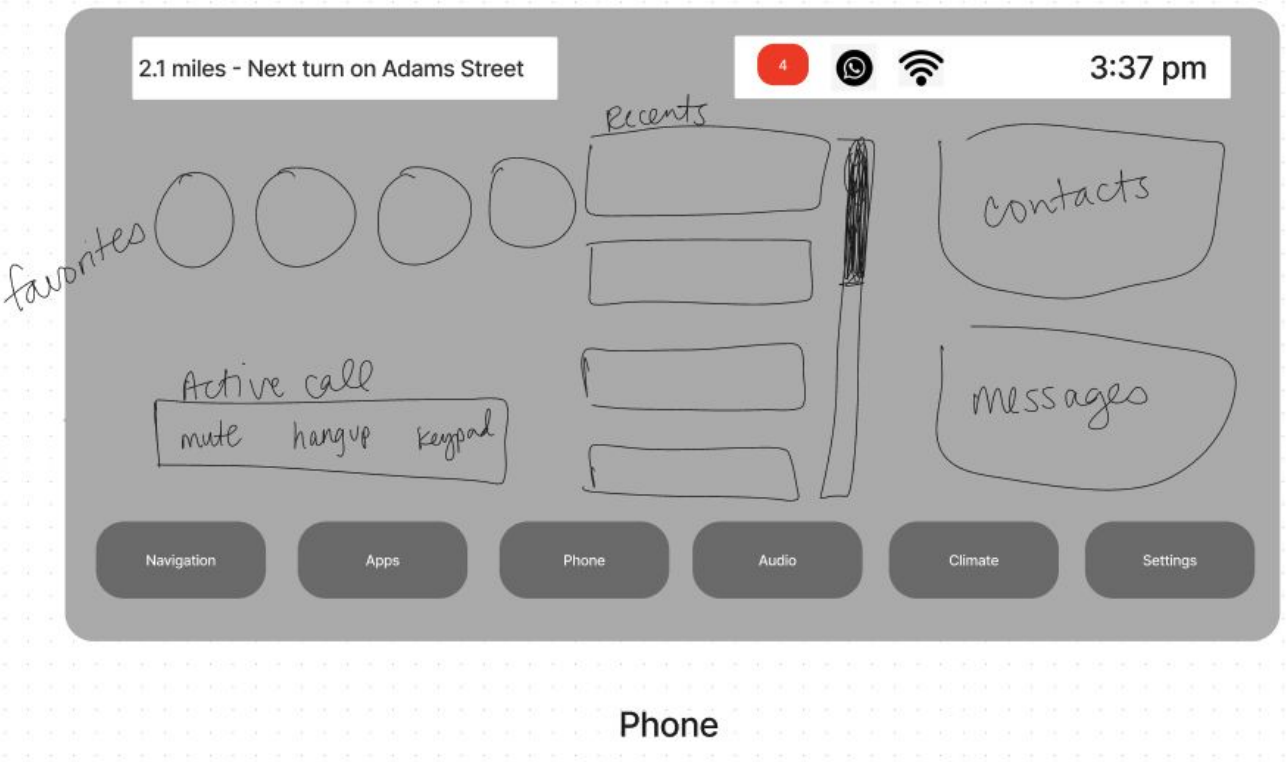


Climate

Next-level IA

We sketched out the 3 sub-screens that were 1 click deeper into the navigation for 3 key tasks based on most commonly used features from competitive research and contextual inquiry

Lo-fi prototyping



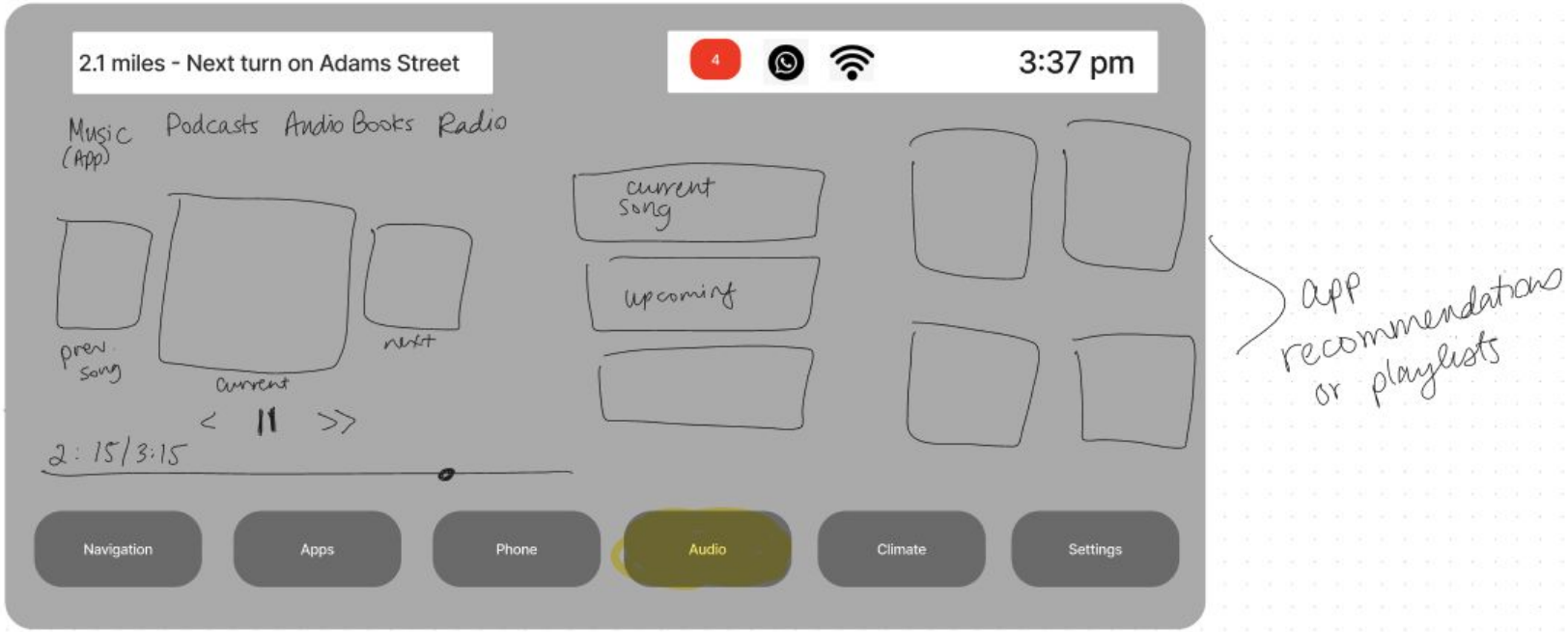
Phone

Prioritizing Safety

We debated whether to include text messages within the UI. While they introduce a distracting element, **users may be more inclined to use their phone to check messages if it is not included in the UI.**

Based on this, we chose to include **text messages that are read-aloud only**.

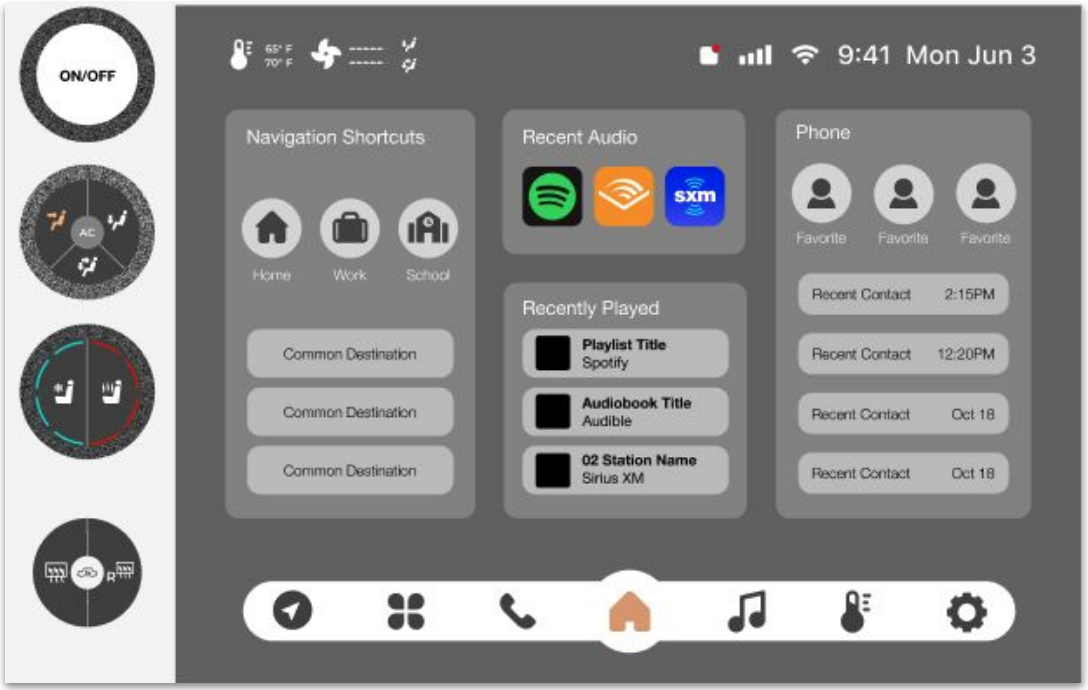
Lo-fi prototyping



Audio

Mid-fi prototyping

Home screen



Designed for 3 Main Tasks

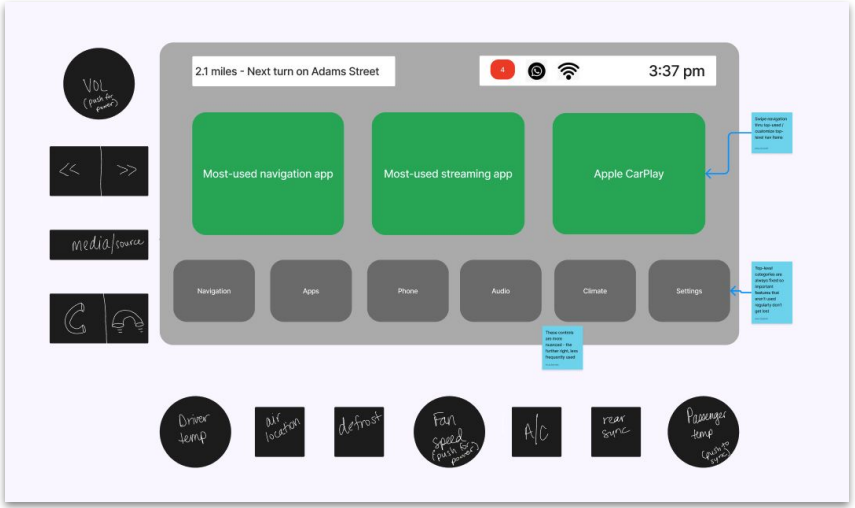
- We smocked up the homescreen, main tactile controls, and one click deeper into nav for 3 main tasks: **phone, climate, and audio**
- **Navigation** was also considered in the home screen design

Mid-fi prototyping

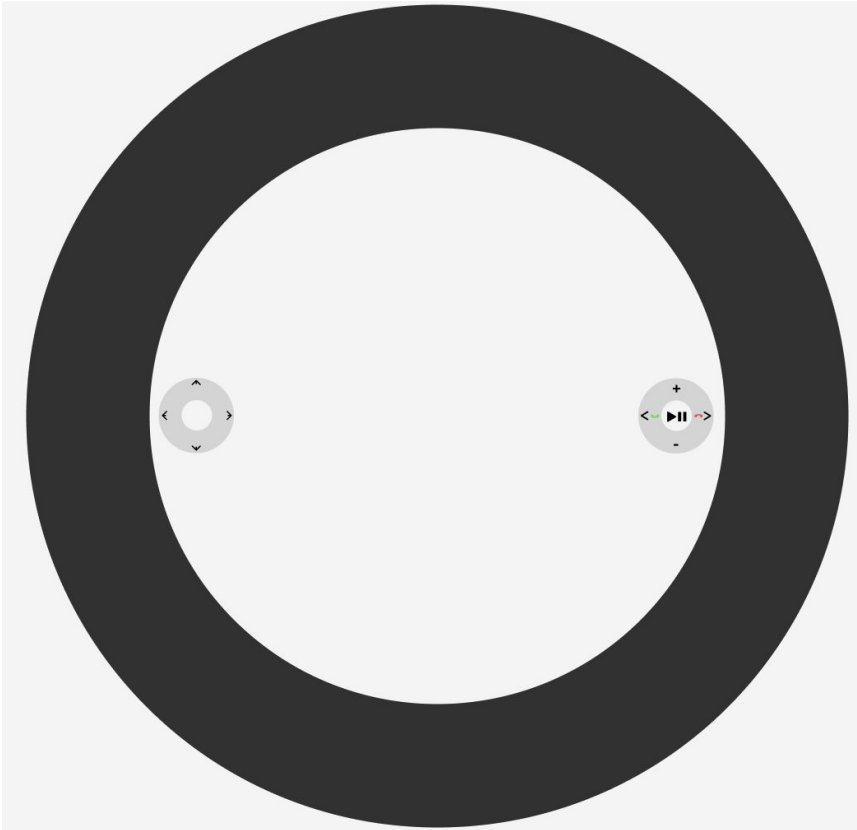
Button Changes

- Driver-only buttons were prioritized for basic audio and climate only
- Audio and phone buttons were integrated into steering wheel controls

Lo-fi home screen + buttons



Mid-fi Steering Wheel Controls



Mid-fi prototyping

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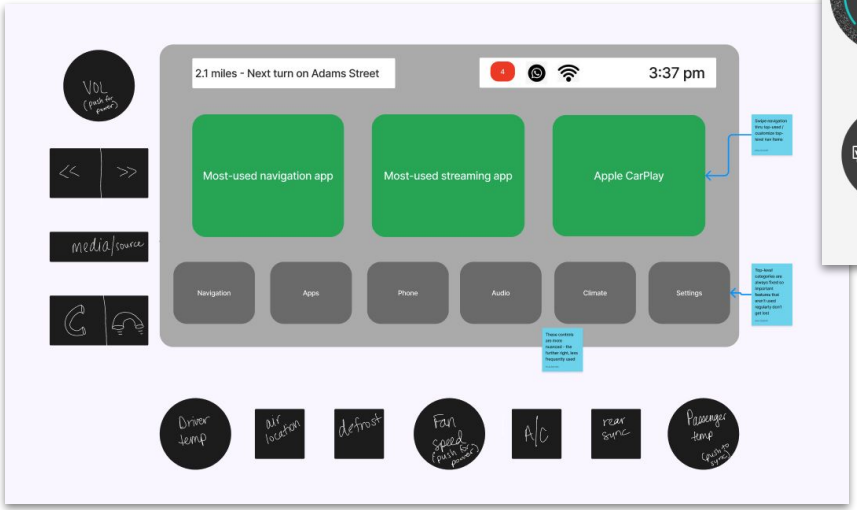
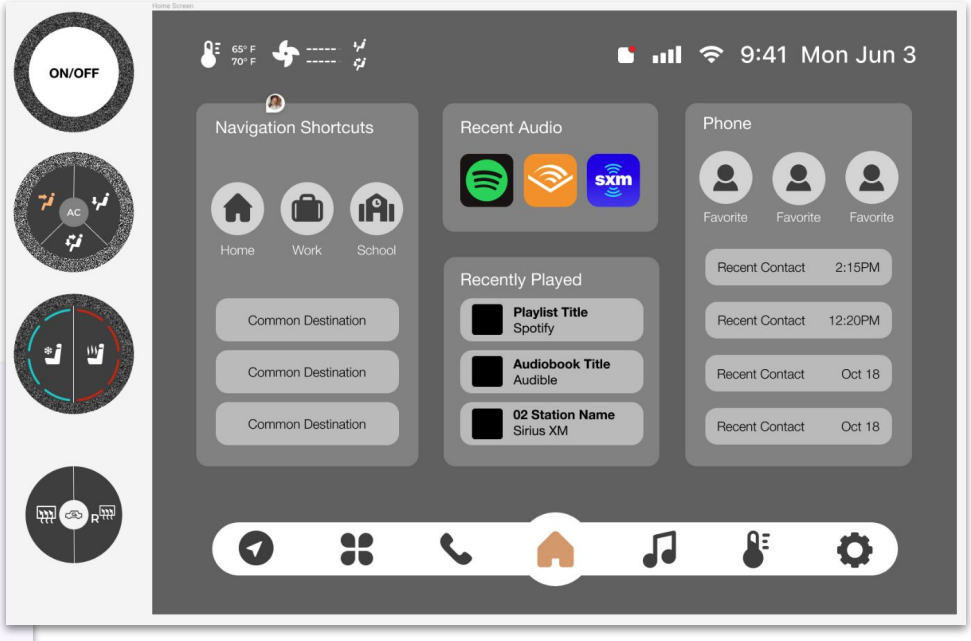
Lo-fi home screen + buttons



Mid-fi home screen + buttons



Home Screen Changes

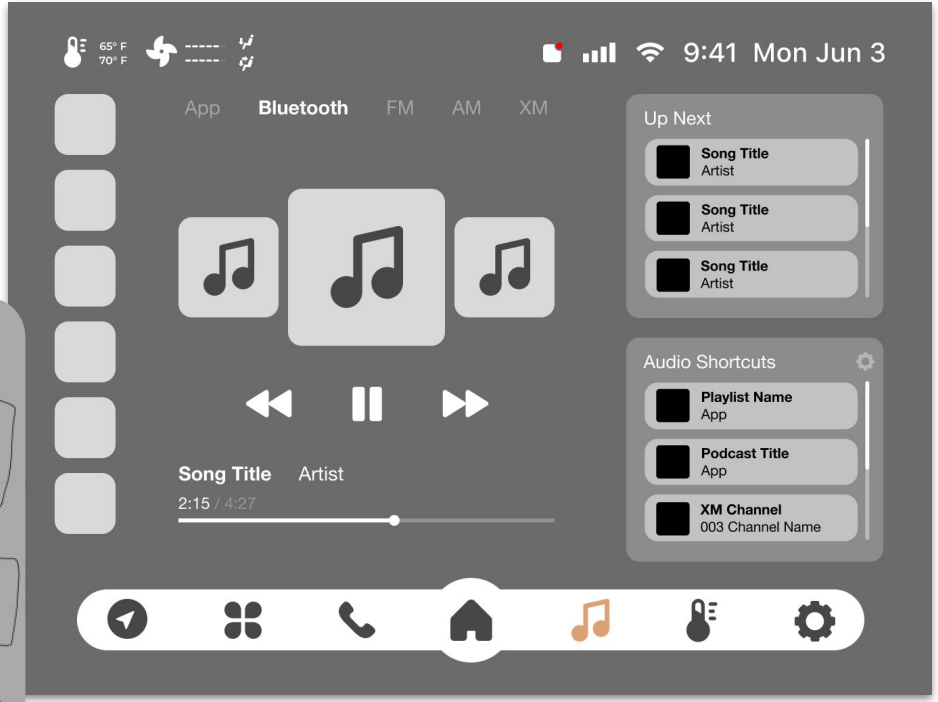
- Apple Carplay was removed in favor of native audio and phone app integration
- Phone history was brought to the home screen

Mid-fi prototyping

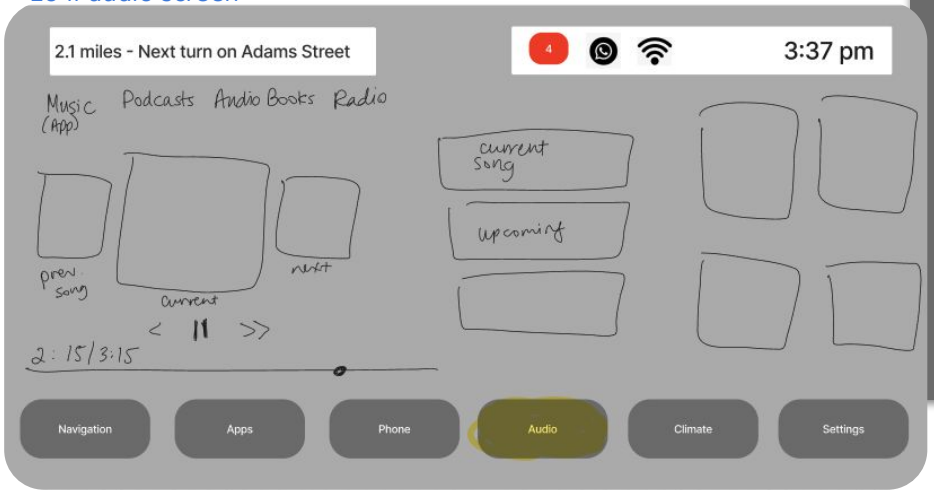
Audio Screen Changes

- Simplified panel structure for better reach zones and learnability
- Maintained overall features from initial conceptualization

Mid-fi audio screen



Lo-fi audio screen

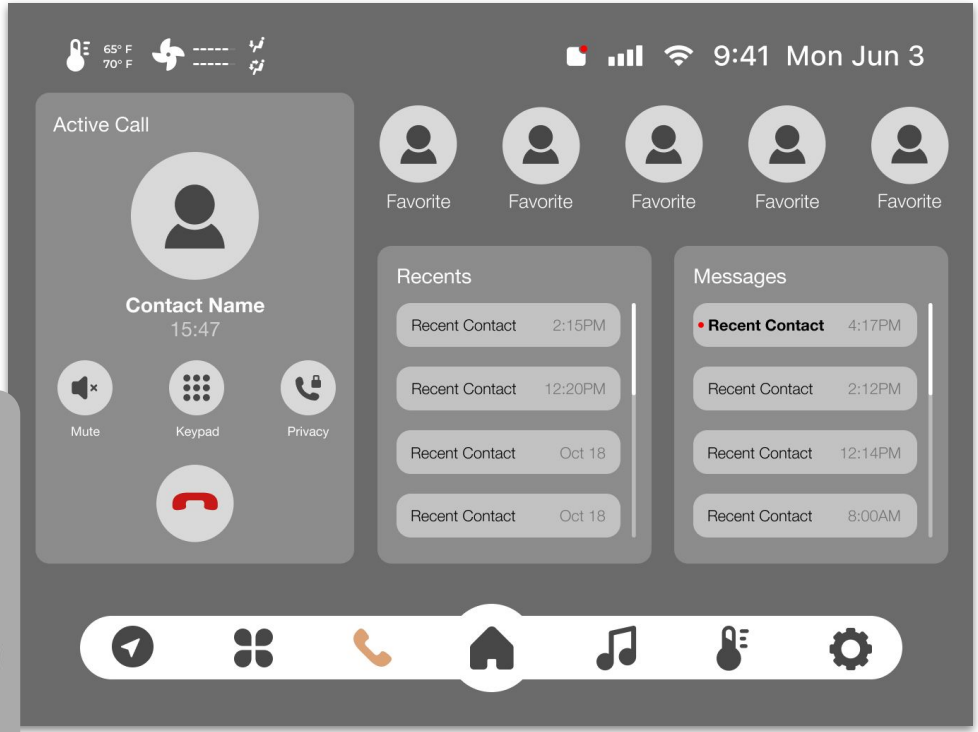


Mid-fi prototyping

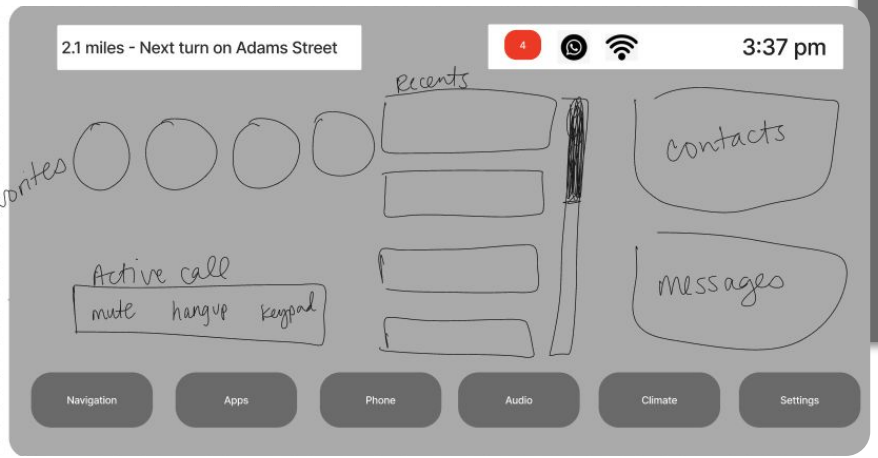
Phone Screen Changes

- Simplified panel structure for better reach zones and learnability
- Maintained overall features from initial conceptualization
- Favorites can be manually set or pulled from phone

Mid-fi phone screen



Lo-fi phone screen

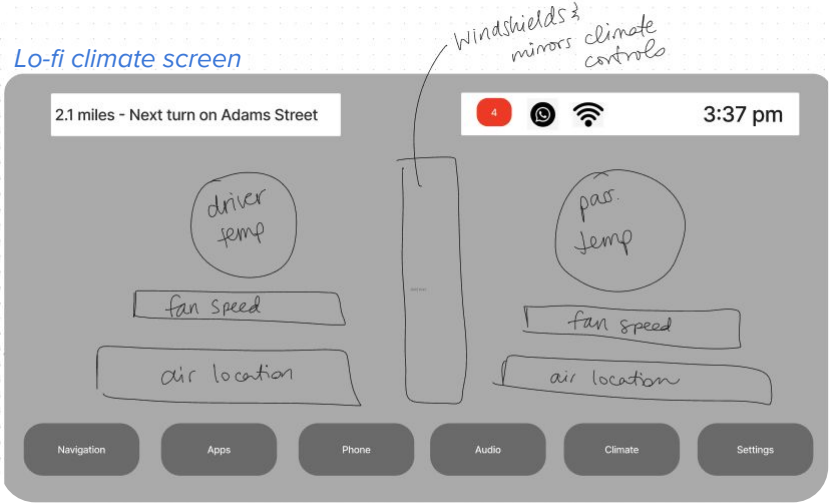


Mid-fi prototyping

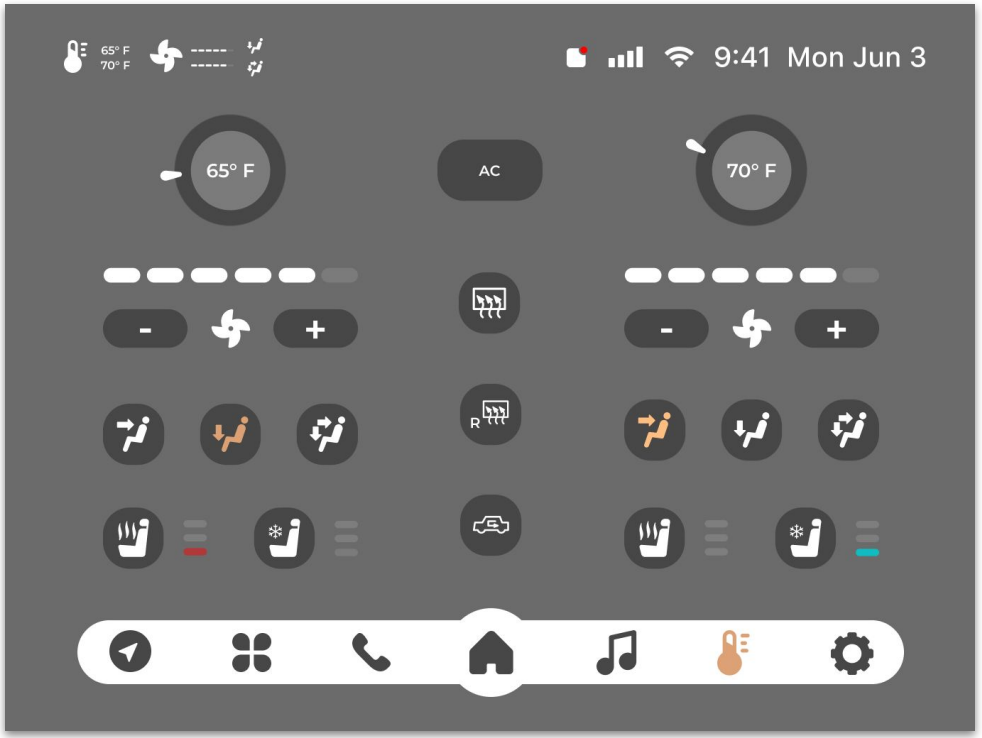
Climate Screen Changes

- Maintained overall structure & features
- Added seat climate controls
- Added current climate control settings in top left to be common across all screens and always visible for button use
- Added lighted indicators to demonstrate current state

Lo-fi climate screen



Mid-fi climate screen



First-click testing

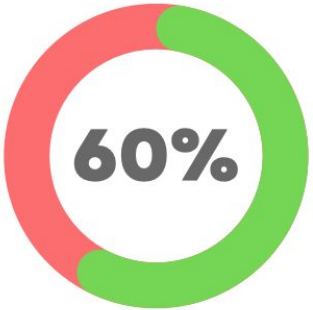
Reasoning & Results

- Since the information architecture of our UI was very flat, we wanted to test success/failure rates of key tasks using the mid-fi prototypes
- We also assessed the time it took to complete each task
- The tasks with acceptable success rates (over 50%) were completed in **10.6 seconds on average**
- **Potential confound to timing data:** Some participants re-read the task description while the timer was counting response time, so times **may not be accurate**
- **2/7 tasks** performed **well** with **80% success**
- **4/7 tasks** performed **okay** with **60% success**
- **1/7 tasks** performed **poorly** with **20% success**

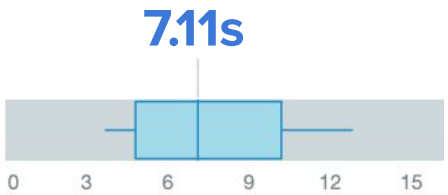
Results: First-click testing

Task 1 - Climate

Imagine you are driving and want to lower the fan speed of your air conditioning. Where would you do so?

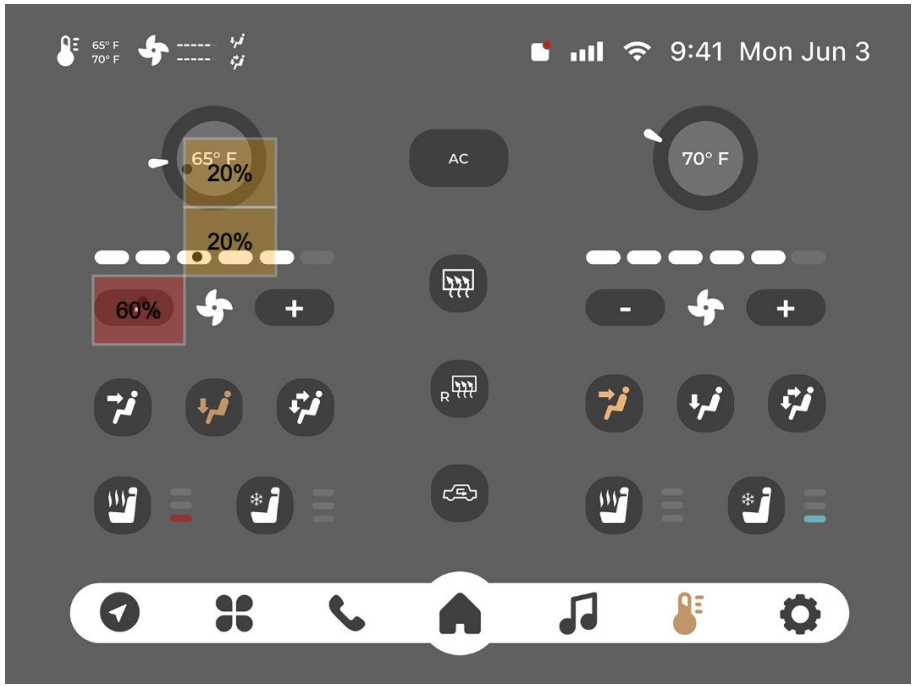


Task 1 Success Rate



Task 1 Time Taken

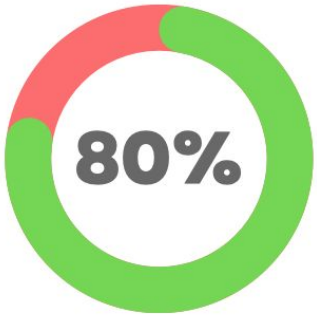
Task 1 Grid Map



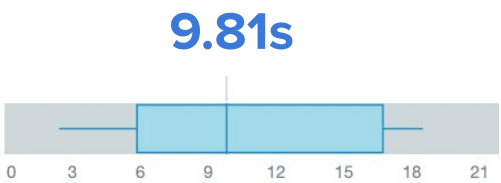
Results: First-click testing

Task 2 - Audio

Imagine you are driving and want to listen to the audiobook you have been listening to all week. Where would you do so?

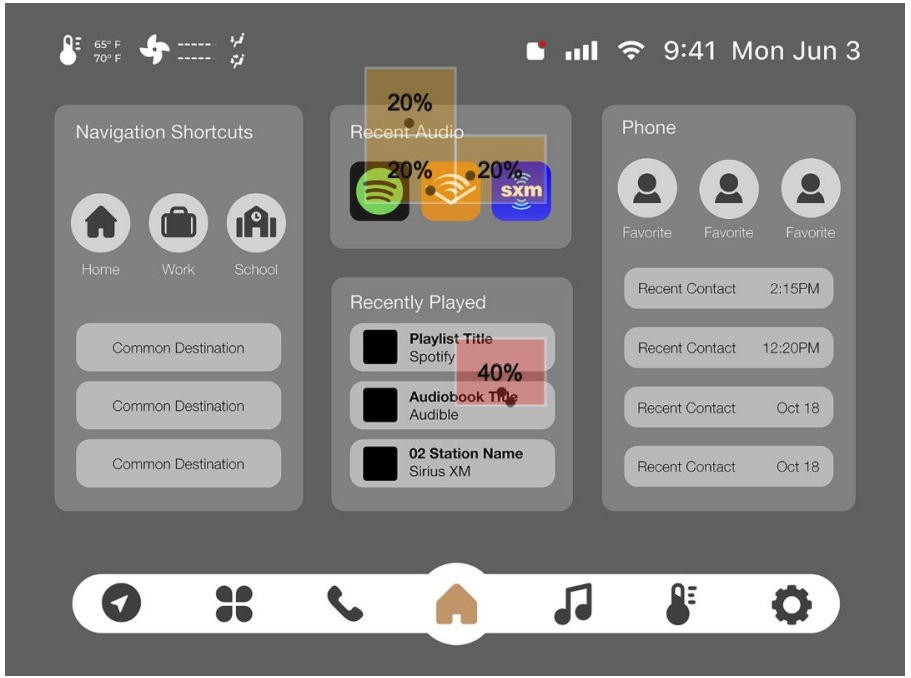


Task 2 Success Rate



Task 2 Time Taken

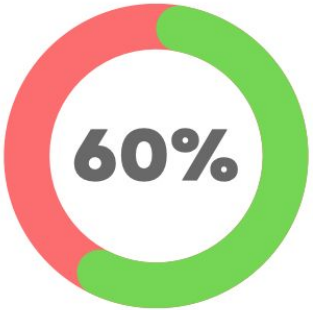
Task 2 Grid Map



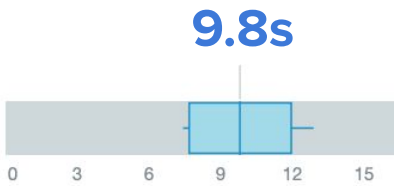
Results: First-click testing

Task 3 - Navigation

Imagine you are driving home from an unfamiliar location.
Where would you tap to get directions?

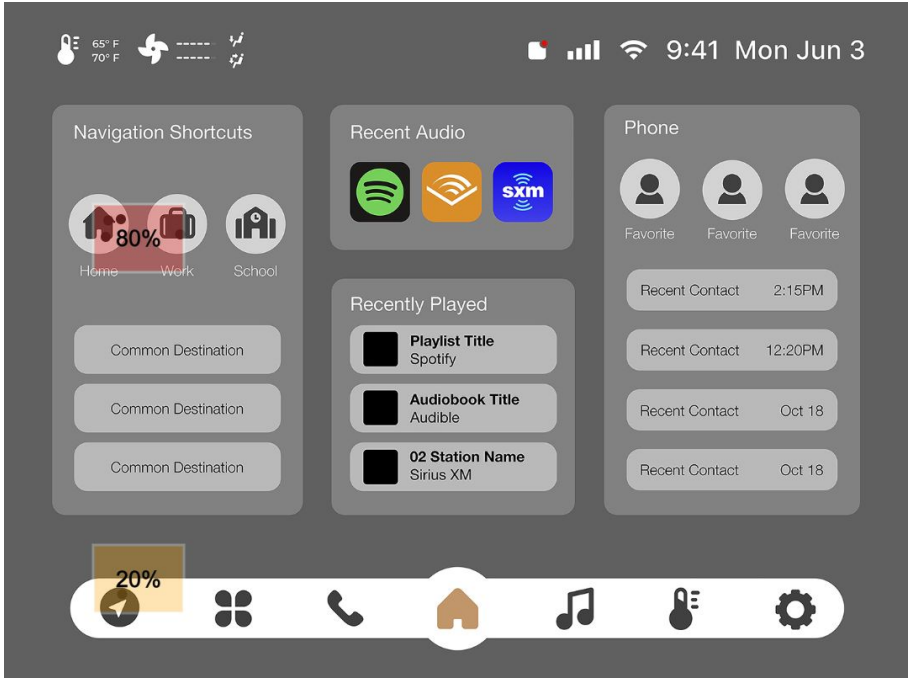


Task 3 Success Rate



Task 3 Time Taken

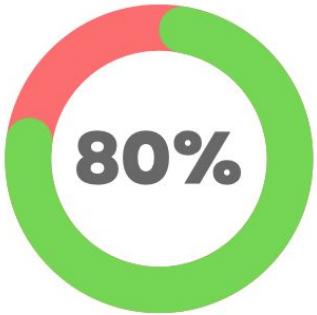
Task 3 Grid Map



Results: First-click testing

Task 4 - Text Message

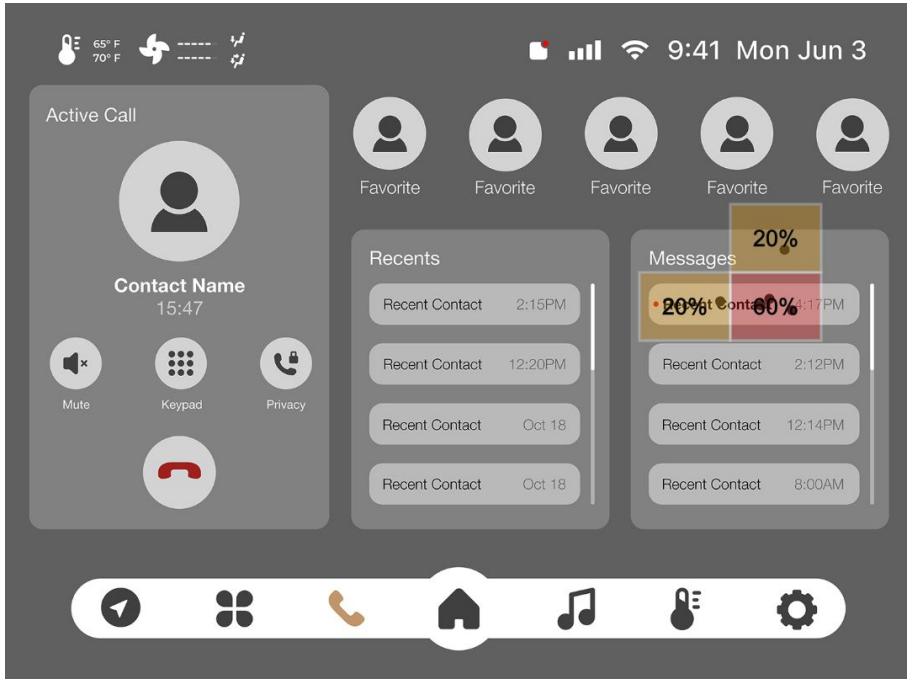
Imagine you are driving and want to hear a text message you just received. How would you do so?



Task 4 Success Rate

Task 4 Time Taken

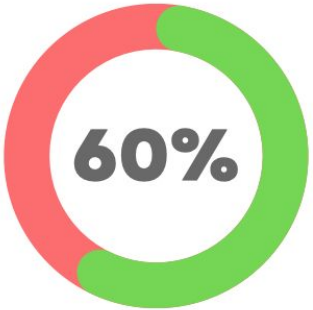
Task 4 Grid Map



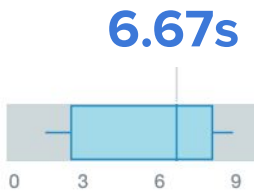
Results: First-click testing

Task 5 - Audio

Imagine you are driving and you want to listen to the next song in your playlist. How would you do so?

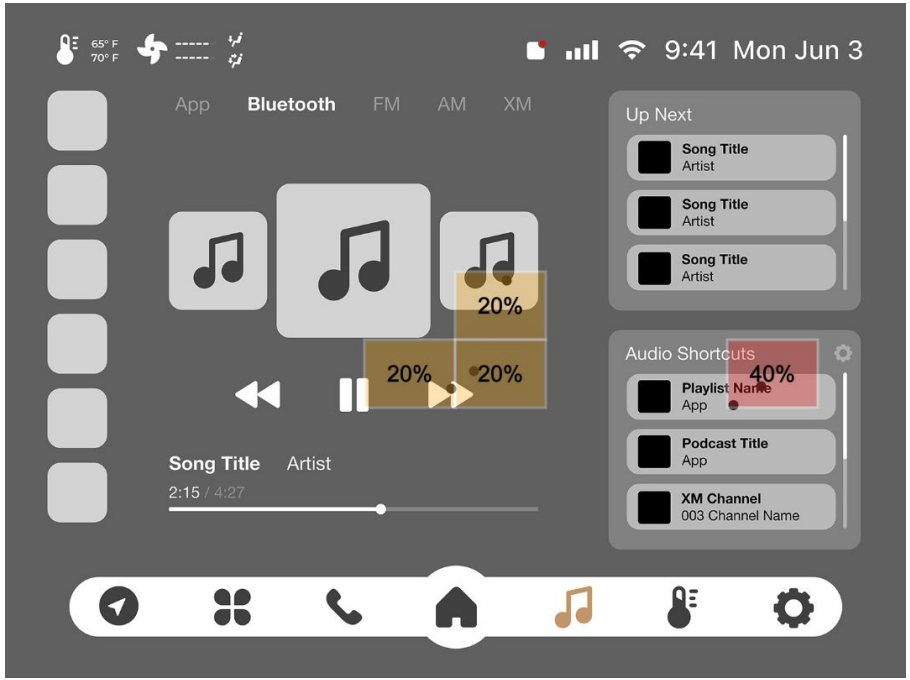


Task 5 Success Rate



Task 5 Time Taken

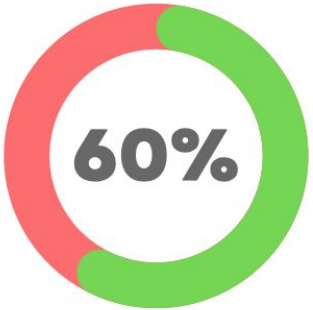
Task 5 Grid Map



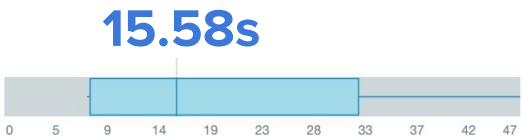
Results: First-click testing

Task 6 - Call

Imagine you are driving home from work while your partner is at the grocery store. You just hung up with them, but you realized you forgot to tell them to buy milk. How would you call them back?

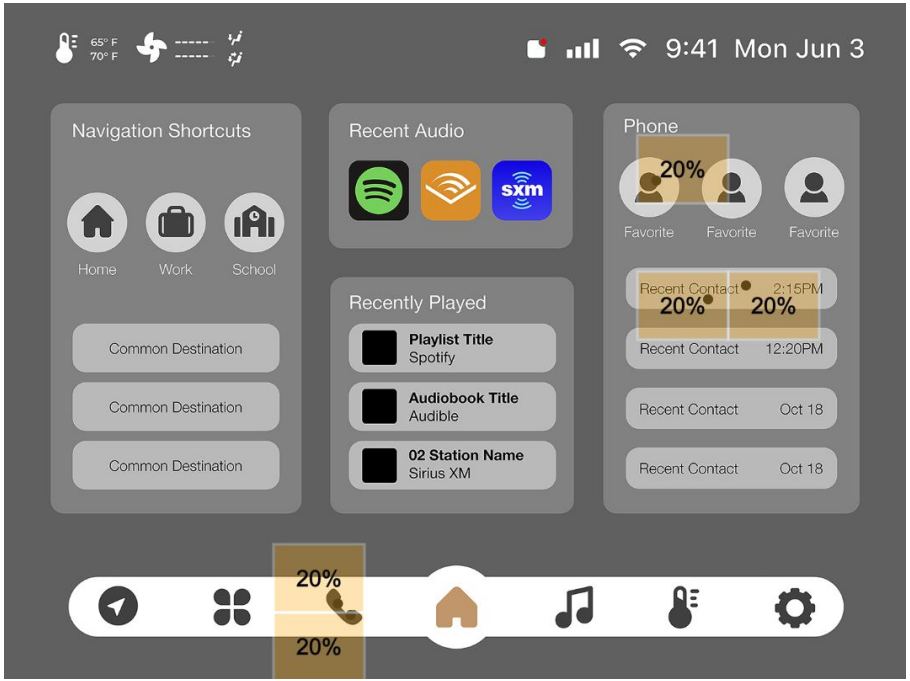


Task 6 Success Rate



Task 6 Time Taken

Task 6 Grid Map



Results: First-click testing

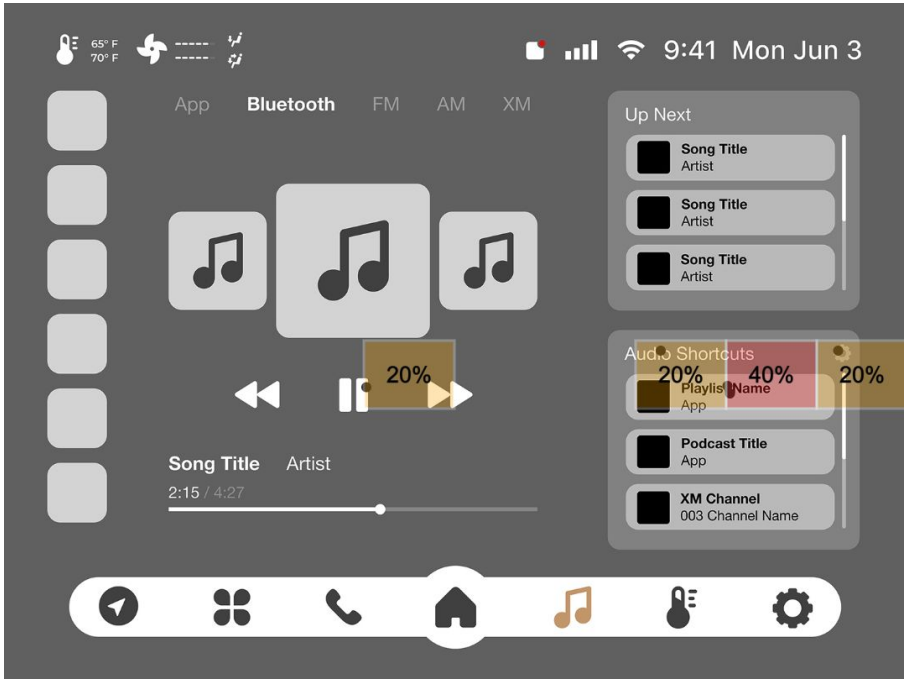
Task 7 - Audio Setup

[Not while driving] Imagine you have just created a new playlist on your favorite music app. You want to set up a shortcut to that playlist on your car screen. How would you do so?

Task 7 Success Rate

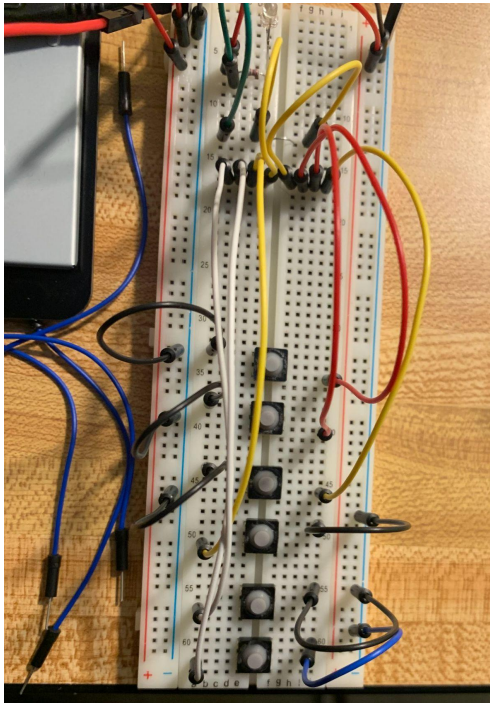
Task 7 Time Taken

Task 7 Grid Map



Hi-fi prototyping

Buttons



High-Level Changes

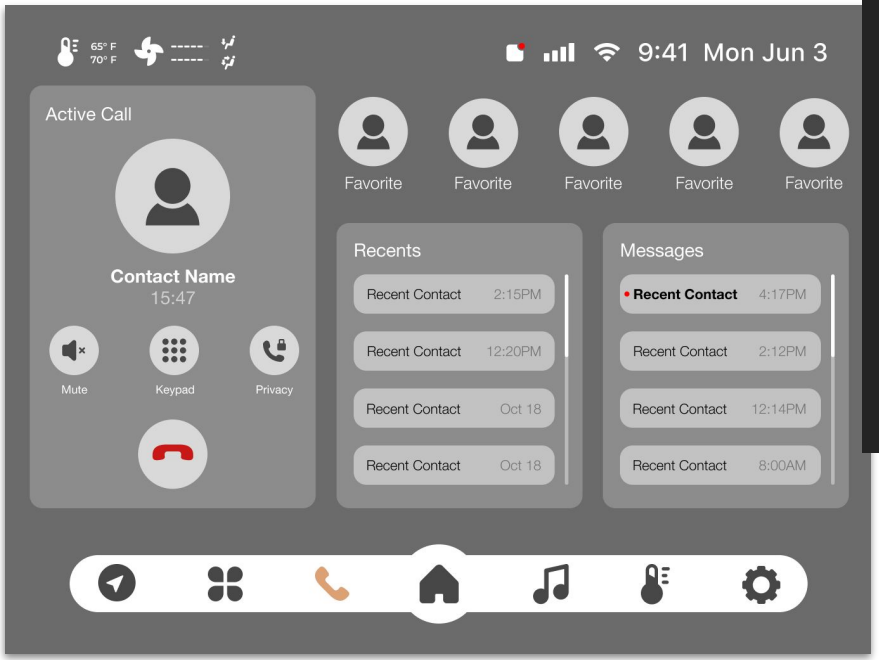
- The elements were resized to fit the Raspberry Pi screen which was 800x480px
- Colors and icons
- Left to right hierarchy of navigation icons

Button Changes

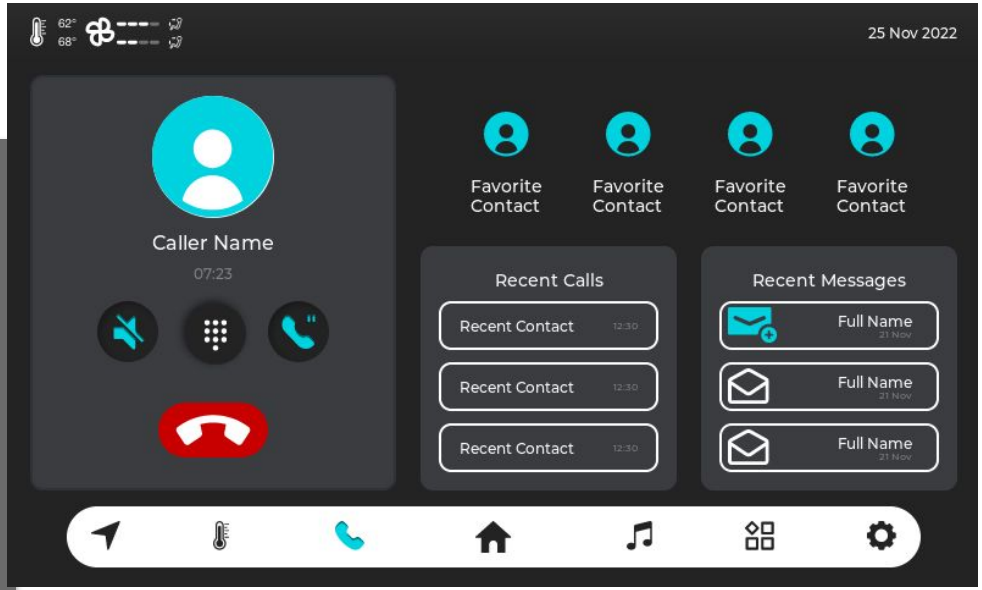
- Separated the potentiometers from buttons
- Used the car's original steering wheel buttons which was similar to what we designed in the mid-fi prototype
- Had too many wires, so only the high level button navigation elements were prototyped

Hi-fi prototyping

Mid-fi phone screen



Hi-fi phone screen

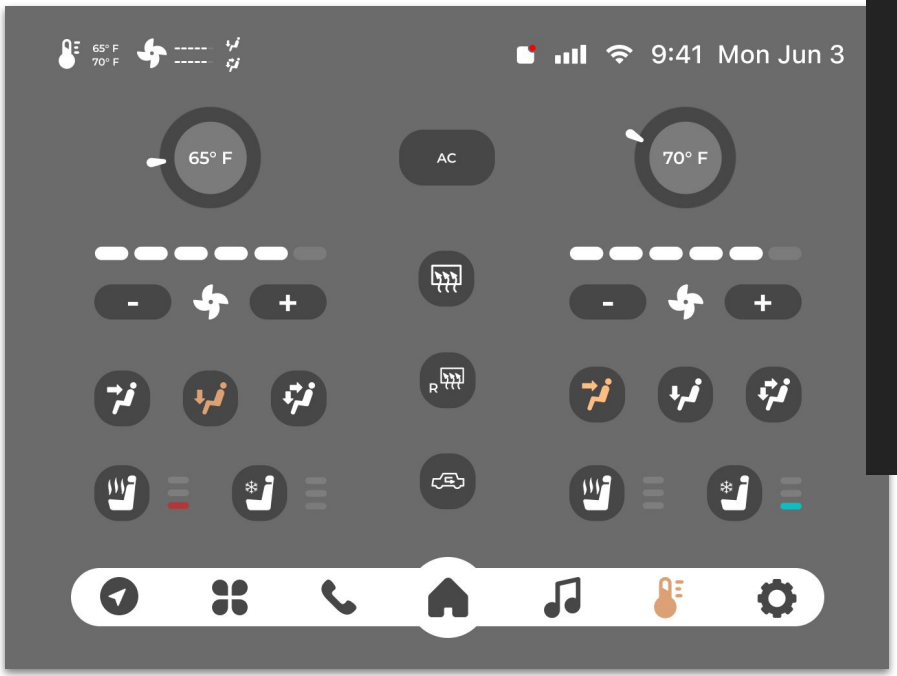


Phone Screen Changes

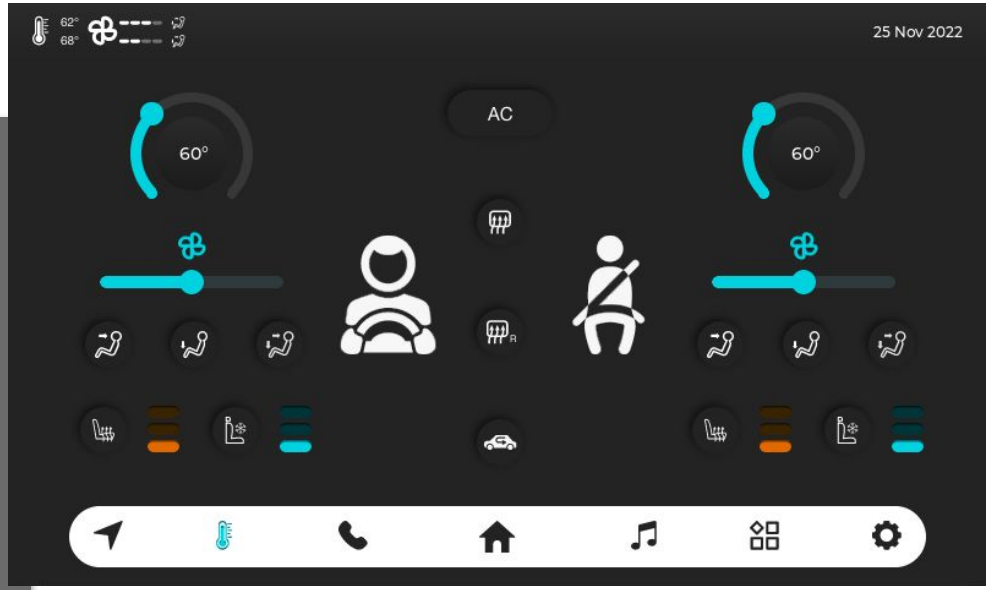
- Only aesthetic changes and reductions in number of contacts shown in each frame due to space constraints within physical prototyping tool

Hi-fi prototyping

Mid-fi climate screen



Hi-fi climate screen

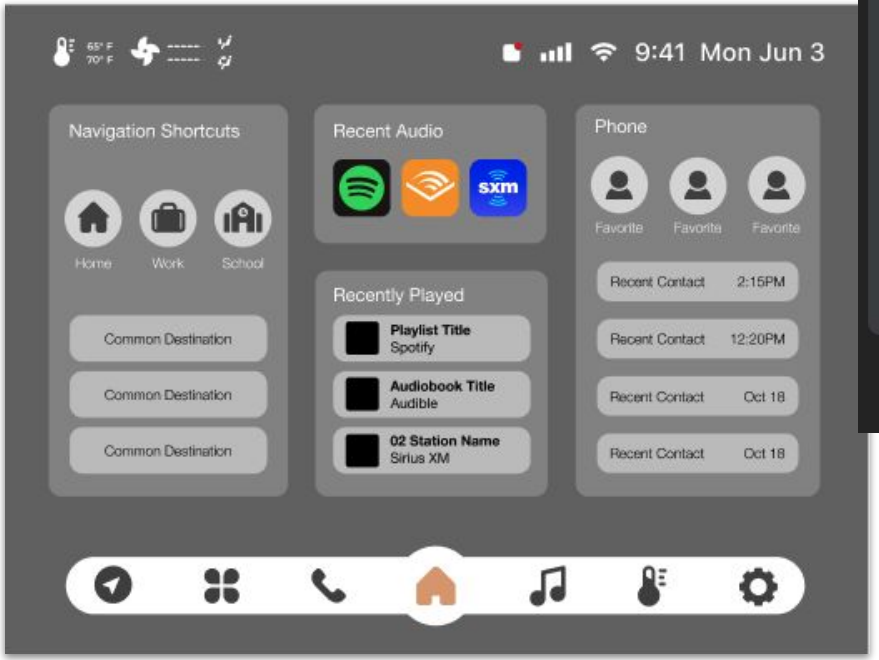


Climate Screen Changes

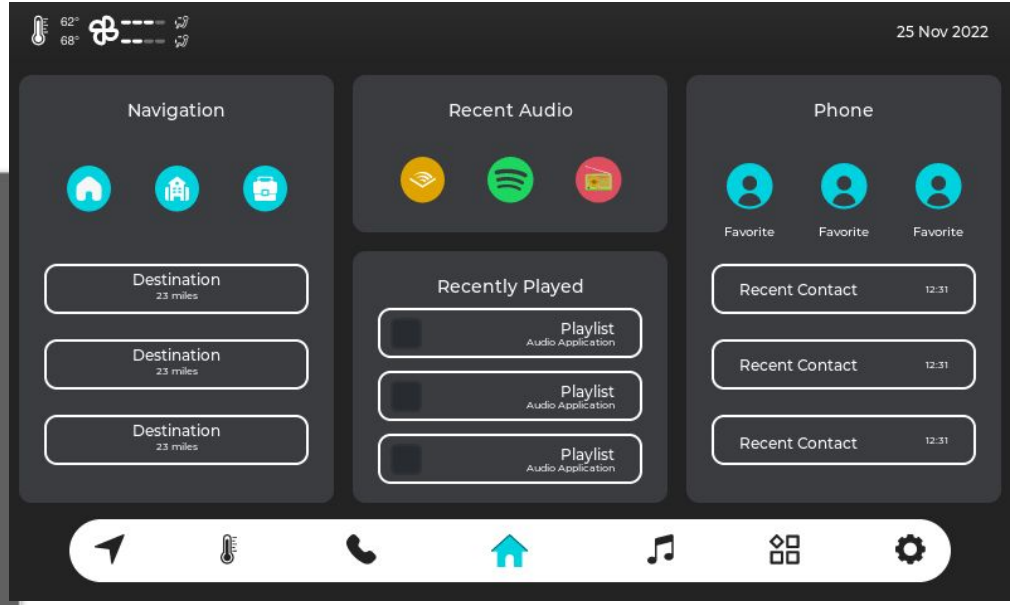
- Added labels for driver and passenger based on cognitive walkthrough feedback
- Fan setting was changed to a slider based on first-click results.

Hi-fi prototyping

Mid-fi home screen



Hi-fi home screen

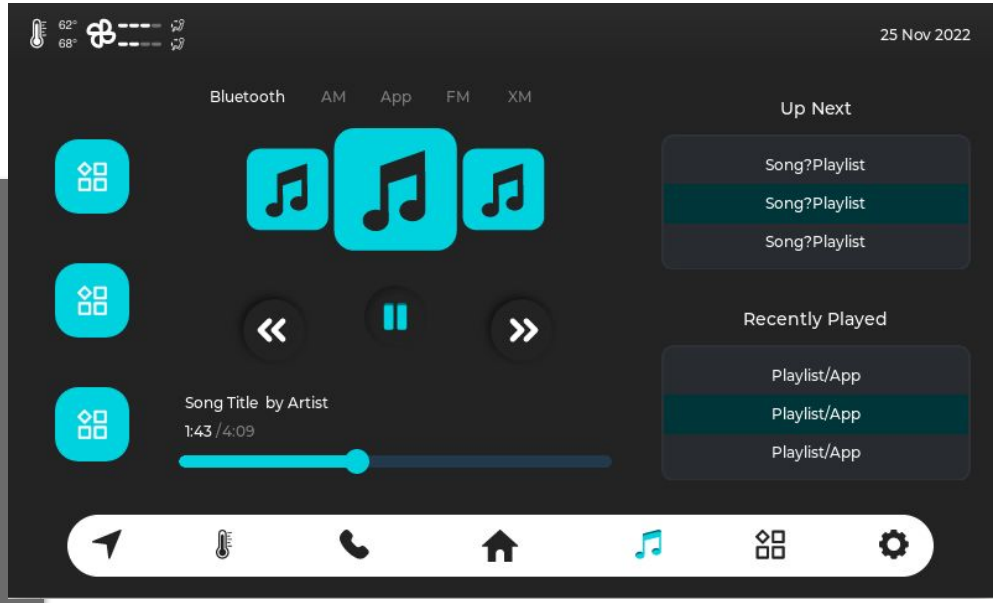


Home Screen Changes

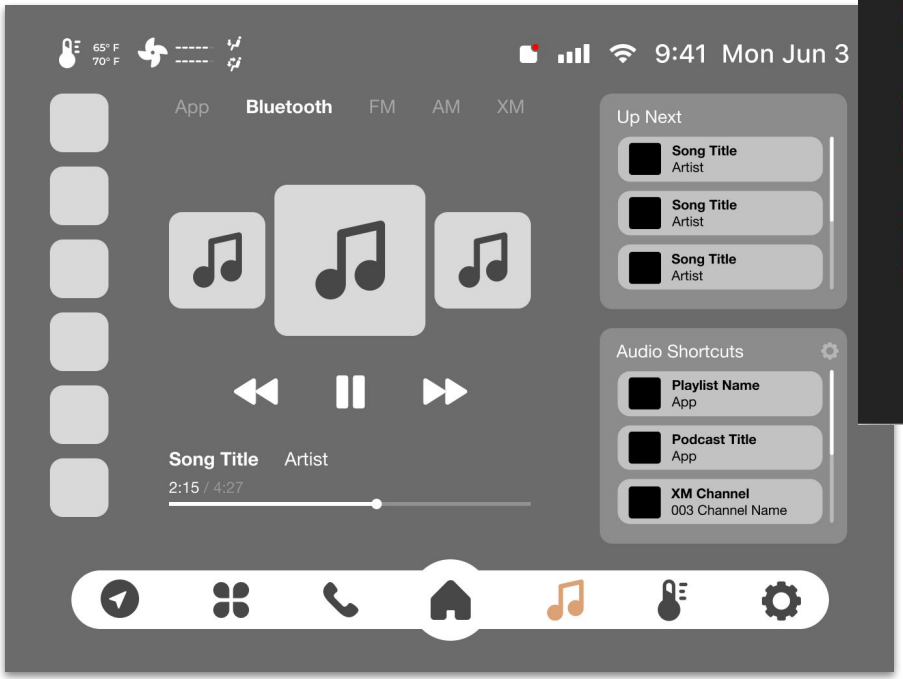
- Aesthetic changes only to main screen
- Home icon was removed from larger circle design based on feedback from cognitive walkthrough indicating the larger circle on home only may be confusing on other screens

Hi-fi prototyping

Hi-fi audio screen



Mid-fi audio screen

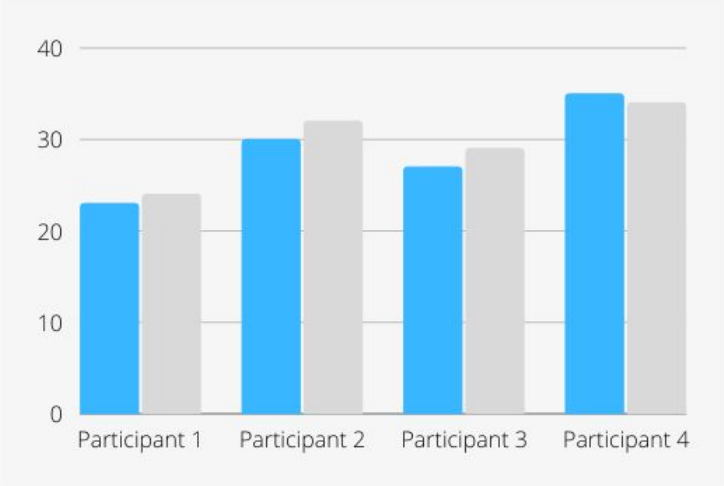


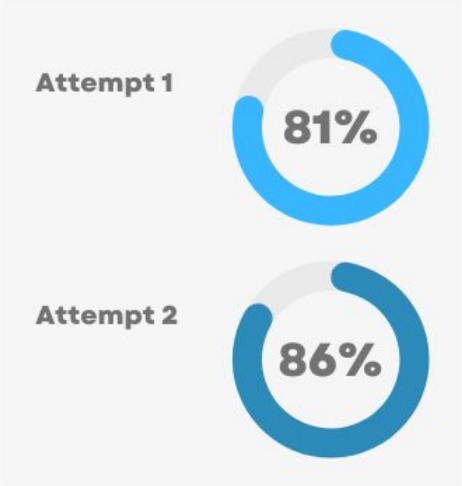
Audio Screen Changes

- Changed the scroll list for “Up Next” & “Recently Played”
- Reduced number of apps shown on left sidebar based on space constraints of physical prototyping tool

Results: Usability testing

TASK PERFORMANCE





In order to assess if the participant has been able to learn the layout of the buttons quickly, two tests were conducted one after the other to check if there was a significant difference in driving performance by comparing both tests

Results: Usability testing

Key Findings:

- Except for one participant, participants generally had a **slight improvement** in driving scores.
- Although overall score of the users improved in the second attempt, some drivers who scored a point in the first attempt on a specific prompt, **failed to repeat the success** the second time.
- There was **no clear pattern** in how drivers managed to score higher points in the second attempt.
- There appears to be evidence of bias as users seem to be more aware of their driving because they are being observed. This could have induced a certain level of **bias** which means that a deeper **statistical analysis with a larger sample size** is necessary.

Discussion

Discussion: **Analysis**

Research, methods & designs

- Overall the research methods were appropriate given the project
- The **competitive research** and **literature review** were instrumental in identifying which features to include in our designs
- The **card sorting** results were less helpful than we hoped. We found more success eliminating outliers and subjects who didn't own their own car with with a touchscreen UI.
- Within the 3 rounds of **prototyping**, we made several changes to the information architecture and display of information based on the technical constraints of each prototyping tool (e.g., iPad, Raspberry Pi)
- The **cognitive walkthrough** performed by another team was helpful in identifying a few problem areas of the UI for improvement.
- Our **first-click testing** helped us understand initial impressions of the UI and get an initial time on task measure.
- Our **usability testing** helped us understand learnability of our UI and usability of the physical prototype.

Discussion: **Analysis**

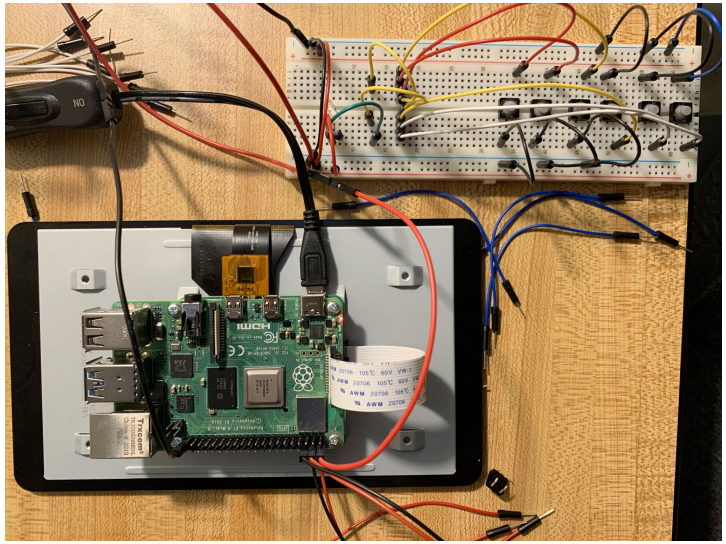
Meeting project goals

- We removed many features through card sorting to reduce the cognitive load of the UI (it was clear that many were confusing or not necessary)
- We ultimately had to narrow the scope to include mostly the touchscreen UI, which changed our results and deviated from our initial vision for the project which included more of the full dashboard with tactile controls
- We figured out how to anchor the most commonly used features through a more flexible UI that surfaced the top-used actions first which met our goal of simplifying design for safety reasons

Discussion: Analysis

Limitations

- **Physical prototype technical constraints:** The aesthetic design, screen size, and button capabilities were limited in our physical prototyping tool (Raspberry Pi).
- **Physical prototype ergonomics:** The prototype was not set up in the most ideal manner due to the number of wires that hindered users pressing buttons. This could be the most important factor negatively affecting the users' button pressing accuracy, which was a factor that was used to measure driving performance.
- **Sample size of the analysis:** The number of people that participated in the usability test (4) was not enough to make strong conclusions. The test should be repeated with a larger number of participants to understand if the solution is viable in the real world.



Raspberry Pi button setup

Discussion: **Analysis**

Future Opportunities

We had many ideas to expand and improve upon the product functionalities, but our ideas were limited by a tight time schedule. Considering the amount of work that was done and the ideas that were implemented in a short time span, we can boldly say that we have established a good foundation for future work.

- **Directly connect the infotainment to the car for a fully functional prototype.** By connecting the UI to the car directly, it would be helpful to help understand how the infotainment fits within the ergonomic standards of each car. This could give us insight on how to customize the UI for cars from different vendors

- **Real-world testing.** The physical prototype was tested in a parking lot with the participant acutely aware that they were being observed, which may have introduced bias. Our literature review also indicated that participants in in-vehicle tests tended to perform in a manner consistent with what they knew they *should do* instead of what they typically *would* do (Strayer et al., 2011). It is challenging to mitigate this issue in a lab setting, but remote data collection may help alleviate the acute awareness of observation by removing the facilitator from the vehicle.

Conclusion

Conclusion: Project summary

Methods	Findings/notes
Competitive Review	Provided **essential insights** to inform designs, especially which features to include
Literature Review	Helped us **identify the key problems and goals** for the project
Card sorting class activity	Helped us **group and eliminate features** that weren't necessary or were confusing
Lo-fi prototyping	Allowed us to articulate the **strategy for accessibility—contextual navigation** based on user data/usage
Mid-fi prototyping	More **clearly designed layers of navigation** and include other necessary features
Usability testing (first-click)	Identified **key problematic tasks** that had lower success rates/time on tasks which needed improvement in hi-fi prototypes/for future research
Hi-fi prototyping	Allowed us to emulate a **true experience of sitting in a car** and included 3D designs
Usability testing	Added the **tactile interactions back into testing** for more accurate results

Conclusion: Meeting project goals

1.

Generate an automotive UI that prioritizes safety through use of tactile buttons

Measures - Usability Testing:

- Frequency & time spent looking at interface
- Task success rate in absence of visual focus

Although many key tasks in first-click testing had good success rates, this would need more validation in an in-vehicle context as a next step

2.

Reduce cognitive load by removing features that are too complex or unnecessary

Measures:

- **Usability Testing -** Reduction of time on task
- **Hybrid card sort** - Cards categorized as unneeded

The project would benefit from more rounds of card sorting with a stronger sample of participants.

Usability testing time on task should be reduced to 1-2 seconds for safety reasons.

3.

Prioritize of most commonly used features to be most easily accessible within interface

Measures:

- **Hybrid card sort -** Frequency of cards
- **Hybrid card sort -** How cards are organized
- **Contextual inquiry -** Frequency of feature use

We effectively problem- solved for a accessibility by making navigation contextual based on user data

Supporting Materials

Protocol:
Contextual Inquiry

Preface: Today we're trying to understand how people use the infotainment systems in their vehicles. There are no right or wrong answers, and this is not a test. Please complete the tasks as you normally would. Please do not complete anything you feel unsafe doing while driving.

Background Questions:

1. What kind of car do you have?
2. Do you use the voice assistant in your car? If yes, how often/in what context?
3. How long have you been driving a car?
4. How long have you had this car?
5. How many miles/how much time do you drive in a week?

Scenarios:

- Car is Parked
  - Go through your routine before you start moving
  - Set a navigation route
  - Walk me through the favorite features of your infotainment system (at the end of observation)
- Car is moving
  - Answer/initiate a phone call using the car (call log visibility, hands-free calling, how do they answer the call, or initiate the call)
  - Change music choice
  - Change climate control
  - Using backup camera
  - Use of voice recognition features
- Car is stopped at a light or a stop sign
  - Change music choice
  - Change climate control
  - Make a change to navigation route (add a stop)

Things to Observe:

- What kind of buttons does the car have on the dashboard? Steering wheel?
- What apps are available within the options menus?
- Structure of navigation? Take a content inventory of the car's infotainment.
- Structure of infotainment center stack (touchscreen position, buttons, etc.)
- Lag/response rate of infotainment system
- How they connect their phone (plug in or let Bluetooth connect)

Closing Questions After Observation:

1. Can you tell me why you {action that they did during the observation phase}?
2. What are some features you like about your car's infotainment system?
3. What are some things you don't like about your car's infotainment system?
4. What are some features you will make sure the next car you buy has?

Card sorting: Screening questionnaire & sorting data

Pre-test questions:

1. Have you ever driven a car with a touchscreen?
   - Yes, my own car has a touchscreen
   - Yes, I've driven a car with a touchscreen but it wasn't my car
   - No, I've never driven a car with a touchscreen
   - No, I don't drive at all

2. Is your car older than 2016? An estimate is fine.
   - Yes
   - No
   - Not sure

Post-test questions:

1. Did any of the items stand out to you for any reason? If yes, please explain.
2. Were any of the items you sorted something you've never used in a car before? If yes, please explain.
3. Do you have any other comments or feedback about the items you sorted today?

Categories

Climate
Control panel
Steering wheel controls
Dashboard
Apps
Media
Navigation
Phone
Settings

Cards

Air conditioning
Android Auto
Apple CarPlay
Audiobooks
AUX port
Blind spot warning
Bluetooth
Cabin heating
Car lighting
Contacts
Cruise control
Fuel
Gaming
Headlight switch
heated seats and windows
Indicators
Individual climate control
Lane departure warnings
Music
Navigation
Phone screencast
Podcasts
radio channels
Rear (trunk) hatch switch
Reverse camera
Settings
SiriusXM traffic information
Sound/volume controls
Speed
Streaming services
USB port
Voice assistant
Wi-Fi hot spot
Windscreen wipers

References

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