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BlokCar: Creating Interactive In-Car Entertainment System For Children

Hsin-Man Wu
Purdue University

BLOKCAR: CREATING INTERACTIVE IN-CAR ENTERTAINMENT SYSTEM FOR CHILDREN

by

Hsin-Man Wu

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THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF THESIS APPROVAL

Dr. Zhenyu (Cheryl) Qian, Chair
Department of Art and Design
Prof. Tong Jin (TJ) Kim
Department of Art and Design
Dr. Yingjie (Victor) Chen
Department of Computer Graphics Technology

Approved by:
Dr. Harry Bulow
Head of the Departmental Graduate Program

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ABSTRACT

Author: Wu, Hsin-Man. MFA
Institution: Purdue University
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Major Professor: Zhenyu (Cheryl) Qian

The research proposes an in-car entertainment system for children to relieve their in-car boredom and further enhance the travel experience. While more and more attention has already been paid on human-car interaction, there is still very limited research considering the interaction between back seat passengers and the car. This project aims to explore the new research area and solve the problems for the children passengers. Based on the research (Price & Matthews, 2013; Wilfinger et al., 2011), many parents reported the quality time they spent with their children in the car was invaluable. Due to the limited space of a car, car travelling is a perfect opportunity to pull a family together and build the memory. However, the travel experience with children is usually not so pleasant for the parents. More than 60% of parents in the survey (Daily Mail, 2011) admitted that travelling without children made them happier. Besides, driving with children also possibly compromise driving safety. According to the previous studies (Koppel, Charlton, Kopinathan, & Taranto, 2011; Wilfinger et al., 2011), children in the car are 12 times more distracting than using cell phone while driving. And the most distracting child-related activities are 1. Looking back at their children, 2. Helping the children and 3. Playing with their children. If searching the keywords about traveling with children, plenty of strategies are suggested to help parents overcome the difficulty. Among them, one of the most mentioned methods is entertainment. Therefore, I further do the user research to understand the real users and their travel experience especially on the entertainment devices. And I found they are having a hard time in preparing the entertainment devices for their children, figuring out what can be played in the car, selecting the adequate toys for the limited space and worrying about the children's eyes health. With the findings and insights, I generate the designs iteratively. Finally I proposed a system composed of three major components- 1. Mobile Application, 2.

Interactive Block- BlokCar and 3. AR Interactive Window. The mobile application helps to better plan and prepare for the trip and also provide a variety of entertainment resources for the users during the car travel. When they arrive, the application records the travel history automatically and generate the memorable data. On the children's side, they play with the interactive block which is connected with the mobile application so both of the parents or the children can engage in. Instead of allowing children to play games on the digital devices, the interactive block attempts to entertain children without compromising the eyes health and to create the variations of toys. Finally, the AR interactive window broadens the playground and allows the children to interact with the surroundings. The whole system is cross-media interactive and location-based. It aims not only to solve the problems of the current travel experience, but also to create the values of a family trip.

CHAPTER 1 INTRODUCTION

In this chapter, I will mainly introduce the journey and the detours of finding the thesis topic, and explain the reasons why I believe this is a valuable topic on which still little attention has been paid. The process of the project from research, problem identification, user modeling, design and evaluation will also be briefly discussed to give the readers an overview of this project.

1.1 Identifying the Topic

Identifying a right topic is always challenging. It may be a journey of trial and error. Sometime, I found some topics are really good to explore, but I would later understand that I probably could not come up with better solutions than those other researchers have done. Obvious problems are easy to find but hard to do better. Therefore, I revised the topic directions several times before I find the current one. However, I don't think the process is a waste of time. Every step makes a meaningful contribution to the final direction. I started the exploration from the domain of GPS, or the location-based applications, because I have experienced many problems with the navigation devices and I didn't find the best solutions in the current market. I am a fan of road trips. I enjoy car travelling with my friends and my family. However, the experience with current technology is not totally satisfying. Hence, I started thinking what I can do to make it better. Then I found many researches have been conducted to solve either the problems of navigation devices or drowsy driving (see Figure 1). Drowsy driving is a big issue for a long-distance travel. It is an influential topic domain so many researchers put

much effort into solving it. But after the research, I found the best solution to this problem is probably just asking the drivers to rest rather than letting them continue driving. Then I turned to the problem about driving boredom and considered the possibility of the application of gamification (Deterding, Dixon, Khaled, & Nacke, 2011). Afterward, I got a chance to test a self-driving car and a question coming into my mind- if self-driving technology comes true one day, do the driving problems still exist? (as Figure 2) Therefore, I changed my target from driver to passenger. I reviewed the relevant literatures and I knew this is a domain for the future of Human- Car Interaction. While more and more attention has already been paid on human-car interaction, there is still very limited research considering the interaction between back seat passengers and the car. And according to the findings from literature reviews and user research, I learned many parents have the problem with travelling with children (Daily Mail, 2011), even though they agree that the quality time they spent with their children in the car is invaluable (Price & Matthews, 2013; Wilfinger et al., 2011). If searching the keywords about traveling with children, plenty of strategies are suggested to help parents overcome the difficulty. Among them, one of the most mentioned methods is entertainment. Therefore, I made the decision for this project to propose an in-car entertainment system for children to relieve their in-car boredom and further enhance the travel experience.

User	Problem	Scenario	Product
Driver ↓ Adult Passenger ↓ Children Passenger	Drowsy Driving ↓ Driving Boredom ↓ Riding Boredom	Frequent long-distance travel ↓ Road trip or long-distance travel	Location-Based Application ↓ Location-Based Gamified Application ↓ Location-Based Entertainment Application ↓ Location-Based Entertainment Device

Figure 1: Journey of identifying the topic

Figure 2: New mode of in-car interaction

1.2 Building the Solutions

The whole process mainly follows the method of Goal-Directed Design, a theory developed by Alan Cooper (2007), with an overall framework based on User-Centered Design. The details about the design process will be discussed in chapter 3. Here I will briefly introduce the relationships among each step and the contributions they made to my final design. The research phase can be divided into three modules- 1. Literature Review, 2. User Research and 3. Competitive Analysis. I did a literature review to

understand the existing research on Human-Car Interaction domain and then find the shortage of research focusing on passengers. I also reviewed the related researches to acknowledge the problems the users are experiencing from the perspective of parents and children, and to explore new technology, which has been applied to improving in-car interaction for the reference. After understanding this domain, I conducted the user research to learn the user's travel experience with children and their expectation. Finally, with recognizing the frustrations and the goals of users, I did research on the existing products and found the gap which have not been filled up. Requirement definition and user modeling are then undertaken based on the analysis and summarizing of research findings. This project has two target user groups- parents and children. Currently, the parents have the problem with the preparation before trips and the selection of the adequate toys for the limited space. They feel digital devices are the best tool to keep their children entertained, but they also worry about the children's eye health. With the findings and insights, I generate the designs iteratively. Finally, I proposed a system composed of three major components- 1. Mobile Application, 2. Interactive Block- BlokCar and 3. AR Interactive Window. The system helps parents to better plan and prepare for the travels and also makes each member in the car more engaged in the family travel. And the interactive block- Blokcar is designed for children to create the variation of entertainment without compromising the eyes health. Besides, the AR interactive window creates a new value of road trips by connecting the children with the surroundings outside of the car. It aims not only to solve the problems of the current travel experience, but also to create the values of a car travel with children.

CHAPTER 2 LITERATURE REVIEW

In the following presentation we will explore human-computer interaction in the automotive domain; discover the problems of long-distance car travel with children; and acknowledge the current technology and research on the in-car interaction for passengers by reviewing relevant literature.

2.1 Human-Car Interaction

In this section, I will explain the process where and how I target the topic in Passenger-Car Interaction domain from the beginning of the exploration of Human-Computer Interaction in car domain to the final on the finding of the gaps in the existing literature.

2.1.1 Definition of Human-Car Interaction

Prior to defining Human-Car Interaction, we need a brief understanding of Human-Computer Interaction (HCI). The history of HCI can date back to 1950s in (Myers, 1998)Shackel's work and the creative project conducted by Englebart in 1960s. With the prevalence of personal computers in the early 1980s, the HCI name became popular and was first documented in IFIP Technical Committee 13 on Human-Computer Interaction in 1981 and the first international INTERACT Conference in 1984 (Myers, 1998). The Association for Computing Machinery (Hewett et al., 1992) defines human-

computer interaction as a "discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them." Dix (2009) defined HCI as “the study of the way in which computer technology influences human work and activities.” According to these definitions, we can illustrate that HCI is a research area that puts more emphasis on the interaction between human and interactive systems; it is not only about the human performance of computer use, but it also concerns the entire environment and system. Referring to the definition of HCI, (Harvey et al., 2011) introduced driving as “an example of human-machine interaction in which the human (i.e., the driver) interacts with a machine (i.e., the vehicle).” They also explained that the interaction with a driver is not limited to the vehicle itself. It includes primary driving functions, such as steering, accelerating, braking, and changing gears and also secondary driving functions (driving tasks will be discussed more in the next section), such as an in-vehicle information system (IVIS). Therefore human-car interaction discussed in this thesis is defined as a research focusing on the interaction between humans and the entire system and environment in relation to the car.

2.1.2 Hierarchy of Driving Tasks

Before the discussion about different types of in-vehicle interaction, it is necessary to understand the hierarchy of driving tasks. The hierarchy of these tasks influences the way we evaluate the interaction between human and car. Different levels of driving tasks correspond with different interactive systems and different behaviors. Driving involves multiple complicate tasks (Regan, Lee, & Young, 2008). In the existing literature, driving tasks are usually categorized into two or three classes (Pfleging &

Schmidt, 2015) - Primary task, Secondary task, or Tertiary task (if applicable). Although the hierarchical structure of driving tasks has been discussed in many related researches, there is still no formal and universally accepted definition. Fortunately, these definitions are actually similar and explainable for one another. The primary task is on the highest level and "comprises all activities that are required to maneuver the vehicle" (Pfleging & Schmidt, 2015), "e.g., controlling the speed or checking the distance to other cars or objects" (Kern & Schmidt, 2009). The secondary task within a two-class group is defined as "all other tasks performed by the driver that are not directly related to driving." (Hedlund, Simpson, & Mayhew, 2006). Conducting secondary tasks won't be a key to successful driving; instead, it's to enhance the experience of driving (Harvey et al., 2011). And the secondary task as one of a three-class group refers to functions used to enhance driving performance or increase safety (Pfleging & Schmidt, 2015), such as "setting turning signals or activating the windshield wipers" (Kern & Schmidt, 2009). Lastly, a tertiary task represents all functions related to the information or entertainment system (Kern & Schmidt, 2009) and also includes communication with the outside or passengers, or drinking and eating (Pfleging & Schmidt, 2015). According to these definitions, in this thesis we will pay more attention to the potential development of the tertiary task (or secondary task) and also the need to ensure that these tasks won't influence the performance of primary tasks or lead to driving distractions.

2.1.3 Interaction and Distractions

Although improving safety, efficiency, comfort, and entertainment of the driving experience are the major objectives of a car manufacturer (Bishop, 2005), keeping safety is definitely the first consideration. Therefore when we design a product to enhance

entertainment of the driving experience, we also need to be careful about safety issues, and one of the major considerations that needs serious considerations is driving distraction. The National Highway Traffic Safety Administration (NHTSA) defined distracted driving as "any activity that diverts attention from driving and takes your attention away from the task of safe driving." Regan et al. (2008) summarized the key elements of distracted driving found by reviewing related literature as follows: "1. There is a diversion of attention away from driving, or safe driving; 2. Attention is diverted toward a competing activity, inside or outside the vehicle, which may or may not be related to driving; 3.This activity may compel or induce the driver to divert attention toward it; and 4. There is an implicit, or explicit, assumption that safe driving is adversely affected." As one of the primary inputs of in-car systems, vision is a resource that causes driving distractions more than sound and physical movement. To be specific, a driver using his single visual resources to seek a specific control is a common reason attributing distracted driving (Pickering, Burnham, & Richardson, 2007). Many researches have been conducted to develop speech dialogue systems to replace visual-oriented controls that will reduce glancing at in-car devices (Schmidt, Dey, Kun, & Spiessl, 2010). Society for Automotive Engineers (Green, 1999) set 15 seconds as the maximum time to complete a task in a moving car. More than 15 seconds is not allowed.

2.1.4 Types of Human-Car Interaction

As cars become more and more complex and multifunctional, the interactions between humans and cars are no longer limited only to the interactions with in-car devices. A car itself is an interactive place now. Many people use cars as a personal space and spend more than one hour in car (NHTSA, 2016; Schmidt et al., 2010). Schmidt

made several conclusions about different types of human-car interactions and categorized them into three types: 1. The use of mobile devices while driving; 2. Interaction using built-in information and entertainment systems; 3. Interaction with smart and autonomous functions in cars. And we will discuss further about mobile use in the following because developing a mobile application for users in a moving car will be the primary mission in this thesis.

The use of mobile devices while driving

As one of most distracted activities in car, the interaction with mobile phones could affect road safety. In many countries, the use of a mobile phone while driving is even banned. Brown et al. (1969) were probably the first group of researchers to study the influence of using mobile phones while driving (Brookhuis, de Vries, & De Waard, 1991). They concluded that although using mobile phone has a minimal impact on driving skills, perception and decision-making are definitely affected. However, a mobile phone can also provide value to the user (Schmidt et al., 2010). Diewald et al. (2011) proposed mobile integration in the automotive domain and raised the benefit of mobile use. First, it is easy to learn and the user need not get familiar with other devices. Second, the new information and technology can be updated quickly, and it is easy to integrate with current in-car entertainment systems. Therefore a mobile phone could be a potential medium for a car, only if it is not a distraction for drivers.

2.1.5 Passenger-Car Interaction?

Although more and more attention has already been paid on human-car interaction, there is still very limited research considering the interaction between

passengers and cars. Most current studies focus on driver-car interaction. The related explorations are discussed only in the research by work by Schwarz et al. (2016) and Inbar et al. (2011). Schwarz proposed an idea for drivers to play videos for infants on the rear seat, and Inbar brought passengers into the discussion of human-car interaction and raised a new area to explore.

2.2 Long-Distance Car Travel with Children

Although children are the major passengers I target for the passenger-car interaction in this project, parents are also the unavoidable role to be involved in a family car travel. In this section, we will review the relevant literature about long-distance car travels from both the perspective of parents and children.

2.2.1 Parents' Perspective

2.2.1.1 Parental Attitude to Long-Distance Travel with Children

In 2013, Price and Matthews conducted a survey to understand the parent's attitude to long-term travel with children. They interviewed 21 women and 4 men who have children now studying in preschool or primary school. They stated that "92% of respondents agreed or strongly agreed that travel should be an enjoyable part of the overall holiday/trip experience." They further explained that because the parents usually have neither the time nor the chance to interact with their children in their busy modern lives, the time they spend in their cars to undertake activities together is particularly

precious. In the study conducted by Wilfinger et al. (2011), one of the participants also mentioned that as a parent, she wanted to talk, play, and sing with her children. She didn't like her children staring at the screen or listening to the music with a headphone. From this kind of research above, we can learn that parents overall cherish the time spent with their children in their cars. However, this is not a pleasing experience for many parents. A survey of 2000 parents conducted in the U.K. (Daily Mail, 2011) discovered that "62% feel happier without their children in the car; 43% feel anxious, irritated, or even angry when their children are present in the car; and 55% admit to losing their temper in long car rides with their children." Evident was that many parents have difficulties traveling with their children even though they value such time together.

2.2.1.2 Distractions Caused by Child Passengers

This issue also causes distractions that may influence driving safety. Based on the definition of driving distraction by Highway Traffic Safety Administration (NHTSA, 2016), any activity influencing driver's attention causing a driver to not focus on driving enough to compromise driving safety can be called driving distraction. In the study by Wilfinger et al. (2011), they found that parents would want to see what their children were doing in the rear seat through the mirror. In 2011, Koppel et al. conducted an experiment in which they revealed in a 16-minute car trip with children, parents looked away from the road for 3 minutes and 22 seconds on average, which was equal to 21% of the time. Overall, car traveling with children is 12 times more than using cellphones in the car. Children are considered as one of the major sources of driving distractions for the parents. The most frequent child-related distractions include 1. turning to look at the

children(16%), 2. assisting them (7%), and 3. playing with them (1%). Interacting with children in the car accounts for 12% of the recorded driving distraction.

2.2.2 Children's Perspective

2.2.2.1 Definition of Boredom

As a passenger, most of us have experienced boredom during car travel. Here I will clearly define "boredom" by reviewing relevant literature and further define "riding boredom." The definition of boredom is widely discussed in literature, but no theory or definition has been broadly used. Researchers still know little about the phenomenon of boredom, even though boredom or feeling bored is common in everyday life (Fisher, 1987). The first documented use of the word "boredom" could date back to 1852 in a novel named *Bleak House* written by Charles Dickens. Thereafter Smith (1955) defined boredom as an "experience which arises from the continued performance of an activity which is perceived as either uniform or repetitious." In 1983, Davies et al. defined boredom as an "emotional response to an environment that is unchanging or in a repetitive and highly predictable fashion." Furthermore, Fisherl (1993) suggested that "boredom is a transient affective state in which the individual feels a pervasive lack of interest in the current activity," and that it is often accompanied by the feeling of making a conscious effort to maintain or return attention to the activity (Csikszentmihalyi, 1978; De Chenne & Moody, 1988; Leary, Rogers, Canfield, & Coe, 1986). With the previous studies, Mikulas and Vodanovich (1993) provided a relatively most comprehensive definition of boredom as a "state of low arousal and dissatisfaction attributed to an inadequately stimulating situation."

2.2.2.2 Research upon Riding Boredom

Though most studies were conducted to define boredom, little attention has been paid to the definition of riding boredom. No formal definition of riding boredom is found in current researches, and few studies mention the phenomenon. As mentioned in the definition of boredom, continuing to do the same thing one time after another will cause boredom. In 2011, Wilfinger et al. conducted a probing study about the in-car interaction for the passenger side. They mentioned that passengers get bored more easily than the driver because the passengers in the backseat don't operate the car or conduct any relevant tasks. In the research work of Inbar and Tractinsky (2011), they also pointed out the issue about riding boredom. They explained that one problem a car passenger has is boredom. Child passengers are more influenced, especially for a long distance trip. In 2013, Hoffman et al. also agreed that for child passenger, a family trip can be boring and further cause the tension in the car. Children have a hard time in keeping entertained and occupied during car travel, particularly when they are caught in a traffic jam or heavy traffic (Price & Matthews, 2013).

2.2.2.3 Children's Behavior During Car Travel

As mentioned in the previous section, children get bored more easily than adults during car travel. Also, because car space is limited and children must sit in safety seats, they can't move around to keep themselves entertained. Therefore it magnifies the difficulty in traveling with children. Based on the research of Wilfinger et al. (2011), they revealed that many children will express that they would like also to control the car. It would make them feel they have the ability to do something else. Nowadays, parents

usually have their own strategies to keep their children entertained. They bring food, toys, books, CDs, and so on to the car. Wilfinger et al. (2011) summed it by writing that "music and video in general were reported to be a powerful tool against boredom." However, one participant stated she thought the technology in the backseat was useful only when all children have the same toys; otherwise because they might fight with each other to grab the others' toys. And if a toy falls onto the floor, a child may scream until it's picked up.

2.3 New In-Car Interaction for Passengers

After finding the gap about the domain of passenger-car interaction and understanding the current experience and cognition from the perspective of parents and children, I will here introduce the relevant new technology and research focusing on in-car interaction for passengers. Only a few such researches have been conducted on this domain. I categorized them into four groups: 1. Inform Design, 2. In-Car Game Design Concept, 3. AR integrations, and 4. VR extension.

2.3.1 In-Vehicle Information Systems

In-vehicle information systems help drivers by providing the meaningful information (Stevens, Quimby, Board, Kersloot, & Burns, 2002). Any device that can provide information to assist drivers could be considered as an in-vehicle information system (IVIS), such as a navigation device, cockpit, audio program, or even a mobile phone and texting. Currently, IVIS's are designed mainly for drivers. Inbar and

Tractinsky (2011) challenged them with a new idea to share the in-car information with passengers. They claimed that sharing the information with passengers can reduce the information load on driver to avoid distraction and keep driving safe. Besides, the participation of passengers can draw their interests in the car travels. Passengers are probably not the major receivers of the information, but they can serve as the incidental users. Incidental users are defined as those directly affected by the system or who would interact with the real users, but they usually are neglected by the product designer (Inbar & Tractinsky, 2011). For example, as an incidental user, children sitting in the backseat can be informed how long before they will arrive and information about destination. That's common on an airplane, but in a car, passengers usually don't receive this information. Wilfinger et al. (2011) also conducted a probe study to understand the activities undertaken in the back seat and proposed the potential design directions for the backseat technology. They mentioned that children would like to take part in controlling the car, so an adequate information-sharing is functional to keep them interested and entertained.

2.3.2 In-Car Game Design Concepts

Besides information systems, gaming environments are also popular on the research domain to enrich the in-car experience for passengers. Several researches are being conducted to explore the possibilities of an in-car game. The player is equipped with one handheld hardware in the form of a directional microphone and one earphone. The player would be assigned a mission based on their locations. In 2009, Brunnberg et al. (2009) proposed a game idea to let the passengers interact with the environment they passed by. They saw the environment as a playground and installed the game elements

outside the window. In the game, the user-passengers would hear a sound from the earphone to tell them what to do and how to use the handheld hardware to target the location and complete the mission.

Furthermore, Broy et al. (2011) also came up with several in-car game concepts that are more focused on the collaboration among each member in the car. Four game modes were in their research. The users who sat either in the front row or back row played the games on digital devices. They shared the game results real-time and had to collaborate to complete the game. Wilfinger et al. (2011) demonstrated the application to their research results by also developing a game concept. They created a quiz-based game to be played in the car. The aim of this game was to make passengers more actively engaged in the game's activity as the car travel.

2.3.3 AR Integration

In the Merriam-Webster dictionary, augmented reality (AR) is defined as "an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera)." AR technology has been being developed for a while and has recently become more and more popular. In car domain, most AR integrations are used to demonstrate information on the front window for the driver's benefit. With more emphasis being put on passengers, several researches start targeting the integration between AR technology and side windows or mobile applications. In 2013, Hoffman et al. developed a game application-Mileys, a novel game idea integrating AR, location-based information and virtual characters. In the mobile game, virtual characters would appear on the map and wait for capture by the children passengers. Once the users got the

character, they could keep it in the application. The steady driving also influenced the health of that character. This project aimed not only to create an entertaining environment for the passengers, but also to consider the engagement of drivers and their driving safety. In 2014, Häkkilä et al. also prototyped an AR window concept in their research. They called the concept an interactive AR social window. Through interaction on the passenger side, the user can interact with the people surrounding by writing the greeting words and so on. This AR interactive window concept is also used by car manufacturers, such as Toyota (Telematics News, 2011) and GM (2012). In their design concepts, the AR interactive window allows users to draw on the window, fly the character through the surroundings, and switch the scenes shown on the window.

2.3.4 VR Extension

Virtual reality (VR) is defined as "an artificial environment experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment" in the Merriam -Webster dictionary. VR technology has extended to the car domain in the past few years. Kodama, Koge et al. (2017) proposed a novel idea to serve car as the motion platform of VR games. When the driver is driving, the passenger could wear the VR devices to play the games with the car moving. In this case, car was perfect to be the motion platform to enrich the game experience. In 2017, Hock et al. also explained the idea in their research. They immersed users in the mobile scenario by wearing the mobile VR head-on display. Moreover, Honda also demonstrated the project -Dream Drive In-Car VR Simulator in 2017 to showcase the future experience of this kind.

2.4 Summary

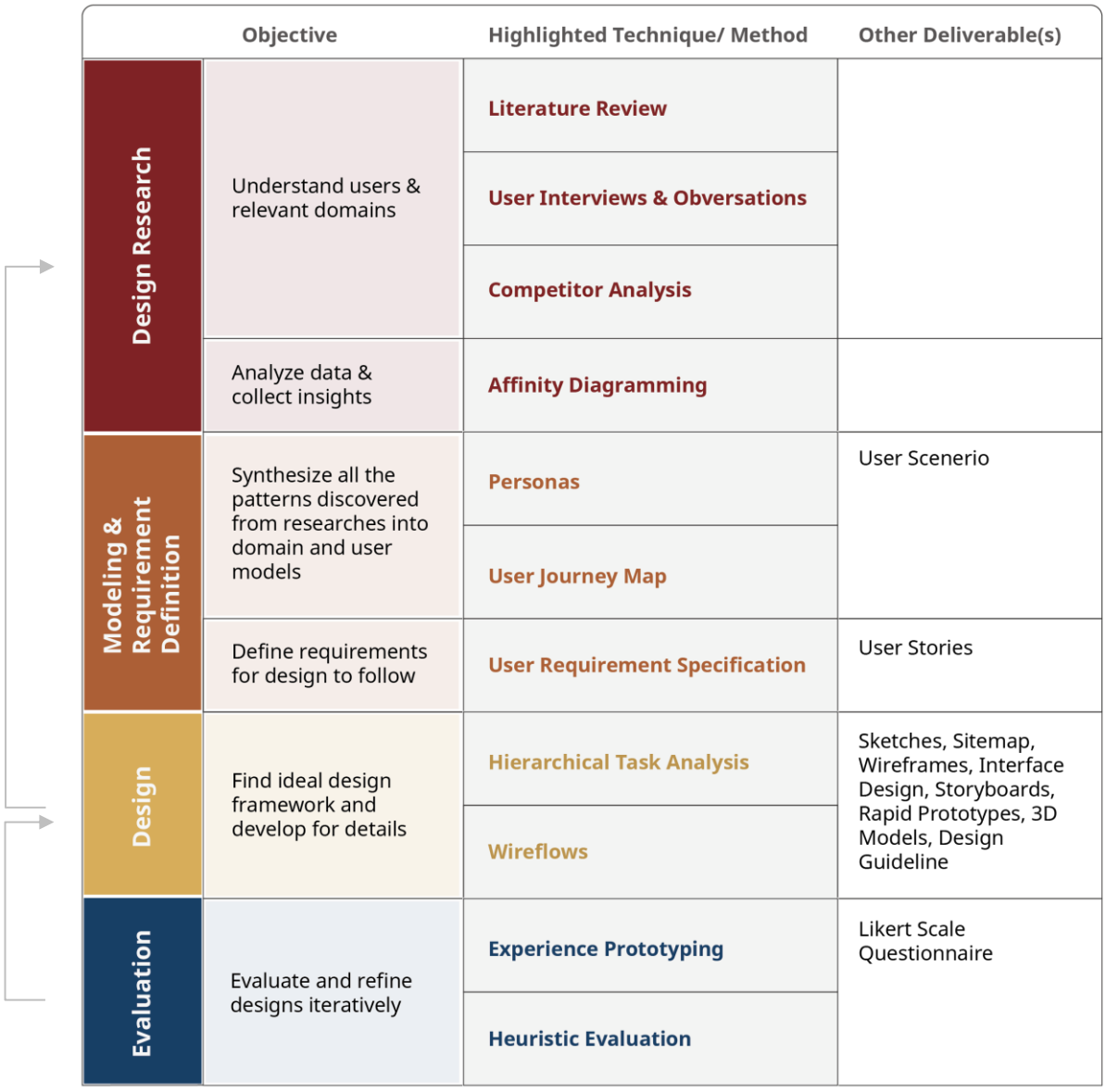
We review the relevant researches about Human-Car Interaction, Long-Distance Car Travel with Children, and New In-Car Interaction for Passengers. We can learn from the research on long-distance car travel with children; though parents value the time spending with their children in the car, most of them feel frustrated about the current experience. And with the new technology, we still find a great deal of possibility to amplify the experience. We can also find that little attention has been paid on the interaction between passengers and car, while most research about human-car interaction has been focused on the interaction with the driver. Therefore, based on the reviewed studies, a new system to reduce boredom for children passengers has a great potential for development.

CHAPTER 3 METHODOLOGY

In this section, I will review all of the methods and techniques I used throughout the project. Here I adopt a mixture of User-Centered Design and Goal-Directed Design. User-Centered Design (UCD) is one of the most broadly accepted theories in the domain of Human-Computer Interaction. It is based on the understanding of users, tasks users conducted to fulfill their needs and the context or environment. Users should be involved throughout the whole process, and the design is iterative. In this project, I employ the process of UCD, which is broad but practical for developing an interactive system, as my major framework and refer to the philosophy and detailed process of Goal-Directed Design, a design methodology developed by Alan Cooper (2007), as a supplement. Compared to Activity-Centered Design, Goal-Directed Design (GDD) is relatively beneficial to create a brand new and differential products from the existing market. According to Cooper (2007), while the goals of users would be kept as the same, the activities users conduct to achieve their goals may be changed with the development of technology. And considering the orientation of this project, which aims to explore a new domain for human-computer interaction, the activities parents and their children are conducting currently in car can be only the references rather than the base of the final outcome. Therefore understanding the goals of the target users is crucial for this project, and Goal-Directed Design can be valuable to follow. Besides the techniques mentioned in UCD and GDD, other useful techniques fitting this project are also considered. In the following, the overview of the methodology will be provided, and the details about the implementation of all methods will be discussed in each corresponding section.

3.1 Process Overview

The User-Centered Design process is composed of three phases: design research, design, and design evaluation (Williams, 2009). Among them, design research is further divided into three steps in Goal-Directed Design, which are research, modeling, and requirement definition. Here I adopt the three phases of UCD as my major framework, and I also draw on research-related steps in the GDD process to develop a comprehensive design process. As an exploration of a new domain, with few existing products for reference, insisting on the essence-user's goals is especially crucial. Therefore in this project, each step is valuable to be highlighted. Here I list an overview of the process, which includes: Design Research, Modeling & Requirement Definition, Design, and Design Evaluation. The diagram (see Figure 3) represents the overall phases, and the applied techniques in each phase will be introduced in the following subsections.



	Objective	Highlighted Technique/ Method	Other Deliverable(s)
Design Research	Understand users & relevant domains	Literature Review	
		User Interviews & Obversations	
		Competitor Analysis	
	Analyze data & collect insights	Affinity Diagramming	
Modeling & Requirement Definition	Synthesize all the patterns discovered from researches into domain and user models	Personas	User Scenerio
		User Journey Map	
	Define requirements for design to follow	User Requirement Specification	User Stories
Design	Find ideal design framework and develop for details	Hierarchical Task Analysis	Sketches, Sitemap, Wireframes, Interface Design, Storyboards, Rapid Prototypes, 3D Models, Design Guideline
		Wireflows	
Evaluation	Evaluate and refine designs iteratively	Experience Prototyping	Likert Scale Questionnaire
		Heuristic Evaluation	

Figure 3: Process overview

3.2 Design Research

The goal of design research is to understand the users and relevant domains, and also to learn the limitations and opportunities. Here are three ways I use to collect data: 1. Literature Review, 2. User Interviews and Observations, and 3. Competitor Analysis. After data collection, Affinity Diagramming is applied to analyze data and find the key insights.

3.2.1 Literature Review

Literature review in this section represents all conducted secondary research used to understand the product domain, learn the limitations and possibilities of technology, discover the problems and opportunities, and all relevant research aiming to solve the targeted problems. The related findings have been introduced in Chapter 2.

3.2.2 User Interviews and Observations

Compared to literature reviews, user interviews and observations aim to understand the real user experiences. While literature may emphasize the importance of progressive developments and advanced applications, interviews and observations are more focused on the users in real life. The goals of interviews and observations, or other user research methods, are to learn the user's goals, the frustrations they face, the behaviors they perform, the activities they undertake to achieve the goals and also the context around them, which might include the environment, other people, artifacts, and so on. The details of interviews and observations will be discussed in the next chapter.

3.2.3 Competitive Analysis

The objective of conducting competitive analysis is to study the existing solutions to the targeted problems. Referring to SWOT analysis, I now analyze the strengths and weaknesses of current products and explore the potential directions and undiscovered areas as the opportunities.

3.2.4 Affinity Diagramming

Affinity diagramming is an efficient technique to organize and analyze a broad range of information subjects and show the relationships among them by categorizing it into a bunch of subgroups. It is also known as the K-J method, which was invented by Jiro Kawakita in the 1960s (Hanington & Martin, 2012). In the research phase, affinity diagramming is finally applied to synthesize and categorize all the findings from literature reviews, user study, and competitor analyses for the modeling and requirement definition phase.

3.3 Modeling & Requirement Definition

Before starting design, setting specific goals and targeting a group of users are important and inevitable. Therefore, in this phase I aim to translate the patterns I found from research into users and domain models. Among them, depicting the user's goals is at the top priority, and it would be presented in a personas and experience map. User requirement specifications are also employed to provide a design guideline to follow. The outcomes of this stage should be put in the center at top priority throughout the whole

process. These user requirements are also good as a standard for us to examine each design solution.

3.3.1 Personas

A persona represents a type of users. Based on the secondary research and primary research, I target a group of users and illustrate them as a real person by using persona. Persona should include a persona's basic information, the biography of the person, his/her goals, frustrations, and other related information. Two personas are in this project. The first is on the parent side: a parent who has two children and would like to travel by car with his/her children. And the other one is on the child side: a kid who is willing to travel with his/her parents but always feels bored during travel by car. In each step of the whole process, I return and confirm that I am going in the correct direction and solving the real problem users face with the personas. This is always a good reference and guideline for designers to follow and examine.

3.3.2 User Journey Map

The user journey map focuses on the overall journey or experience of users in a certain context. It can point out all of the touch points during the whole journey; designers can therefore more easily find the pain points and potential solutions throughout. In this project, I separate the experience of traveling by car into three parts: before, during, and after. The three-stage experience from preparation and planning to travel memories is illustrated on a map with the surrounding context and allows us to quickly discover and point out the problems in this experience. Hence, the user journey map helps to create a more comprehensive model with broad consideration of the context.

3.4 Design

The objective of this stage is to translate all research work into an appropriate solution for the targeted users in a real context. The process is from ideation, framework definition (Cooper et al., 2007), detailed design, and design refinement. The following will focus on the introduction to the techniques and methods contributing to define the design framework. The complete process will be elaborated in Chapter 5.

3.4.1 Hierarchical Task Analysis

A hierarchical task analysis is commonly used to study the detailed steps of a task user conducting with the current system, and through it researchers and designers can find problems with the current system or propose a better solution. But here in the design stage, I use it to frame our system initially and compare the HTA chart of the current system with one of the newest designs. It allows us to discover the problems user might face with our solutions and provides us a potentially better direction to go. I first create a HTA chart based on the initial ideas I have and continue refining the framework iteratively. This is also a base of the site map of the whole system I define later on. Hierarchical task analysis plays an important role in the translation from research to design for this project. It is a research method, but just because it is research based, I can easily employ the research result in our design solutions and make a comparison between the current system and our design. The HTA chart of the new system this project mainly contributes to can be read in Chapter 5.

3.4.2 Wireflows

Wireflows are a mixture of wireframes and user flows that illustrate user flows with low-fidelity wireframes (Laubheimer, 2016). While user flows are normally presented in texts and indicators. The advantage of wireflows is to clearly present the interactions and the relationships among each element on every screen with the visual representations. They are usually arranged like a site map, so this could be a nearly finalized framework for design and evaluation before I jump into designing for the details. And because of the multi-device and multi-channel design of this project, wireflows are especially powerful to review this complex system by checking the connections among each element. Although HTA helps us to ideate design frameworks with the detailed inspection of the user's tasks, and storyboards allow us to develop our design framework with the real context, wire flows serve an important transection between the framework definition with the detailed design by visualizing the relationships and interactions in the whole system.

3.5 Design Evaluation

Iteration can be viewed as one of the major parts of user-centered design. To achieve a successful iterative process, evaluations are essential and inevitable. With the evaluations, I learn about what I must refine and how I can do it. Design evaluations occur in every stage throughout the whole process. Once I get the design outcomes, I will conduct evaluations to make sure I am on the right track. In the following, I will discuss three tools I mainly employ to evaluate design solutions. Experience prototyping is conducted as a formative method to evaluate the design framework in a real environment.

And heuristic evaluations are used as a formative method to test each element in the system by the experts. Lastly, usability testing serves as both a formative and summative method with the real users engaged.

3.5.1 Experience Prototyping

Introduced by Buchenau and Suri in 2000, experience prototyping is “a form of prototyping that enables design team members, users, and clients to gain first-hand appreciation of existing or future conditions through active engagement with prototypes.” It emphasizes the firsthand experience happening in the set conditions, including the environment, artifacts, people, and other involvements. In this project, the environment is a moving car, and the design closely involves the moving element; therefore testing in a moving environment is required. Experience prototyping informs us more about the microinteractions in a real environment and the people involved than staying in an experimentation lab to test the design will. I recruited four people for one test: one driver, a person acting as the parent who is sitting in the passenger seat, another person sitting in the back seat with the child to record the whole process, and a child playing with our design and interacting with the parent. The detail of the evaluation, the result, and the design refinements are recorded in Chapters 5 and 6.

3.5.2 Heuristic Evaluation

Compared to experience prototyping, which is mainly focused on testing for the big picture of the whole system, heuristic evaluations put more emphasis on the discovery of the detailed design. I recruit experts to inspect the design and give us suggestions on each element of the system. Heuristic evaluation can happen earlier in the detailed design

stage to allow us keeping refinements as a formative method. The testing materials can be unfinished or rough in this stage. The goal I aim for when conducting heuristic evaluation at the design stage is to form a nearly finalized system design before it is exposed to the real users. Meanwhile, it can also serve as a summative method to test the final design and obtain the feedbacks for the future work.

3.6 Summary

In this chapter, I review the techniques and methods I use for this project. Here I adopt a User-Centered Design method and Goal-Directed Design method as the major framework. I apply the overall process of UCD and also highlight the importance in the essence of GDD-understanding user's goals as a supplement. This iterative design process is composed of four stages: 1. Design research, 2. Modeling and requirement definition, 3. Design, and 4. Design evaluation. The outcomes of each applied technique and method will be discussed in the corresponding chapters.

CHAPTER 4 USER RESEARCH

The goal of this section is to understand the experience of car travel from the perspective of parents and children. According to Price and Matthews (2013), though children care more about the comfort and joy of the car trip, parents would also like to cherish the time when they can be in the same space with their children and talk with them. Therefore in this research, understanding the experience from two perspectives is inevitable because these two groups of people are both the target users. One-by-one interviews with parents is the major method to be conducted, with observations of children as the supplement. Here I divide the whole process into three phases: 1. Data collection from semi-structured interviews, 2. Data analysis 3. Research findings and user requirements and 4. User experience and behavior modeling. The details will be discussed in the following.

4.1 Data Collection: Semi-structured Interviews

I recruited four participants, including two mothers and two fathers (see Figure 4). Three of them have two kids, the other, a father, has only one. Among the parents with two kids, two of them have one boy and one girl, and the other mother has two boys. Ages of the children range from three to eight, which is the group I mainly target. All the interviewees take a trip of more than one hour with their children at least once a month. These are online interviews with the permission to make recordings. One participant was

interviewed standing with her children by her side so I could ask them follow-up questions. The interviews lasted around 30-60 minutes.

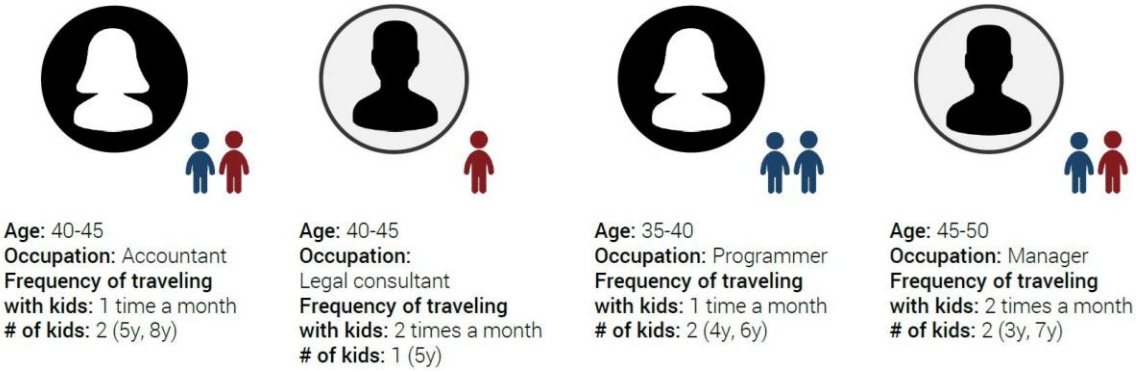


Figure 4: Profile information of interviewees

The interviews were semi-structured with an informal list of questions (see Table 1). The main goals: to understand the overall experience from the perspectives of parents and children, to acknowledge the behaviors of children in a car, to grasp the strategies parents use to entertain their children currently, and also to perceive the meanings of traveling with children for the parents.

Table 1: Interview questions

Experience about longer trip with kids	• Have you even traveled with kids in a longer distance? • How do you define a long trip? How far? • What's the purpose normally? How often it is?
Preparation and differences	• How do you plan your trip? Do you have any preparation? (Any equipment?) • Is there anything needed to be cared? • Can you illustrate the whole process? • Will you have different preparation for traveling with a kid? Or multiple kids?
Activities and behaviors in car	• What will your kids be doing in car? Could you illustrate it more detailedly? • What do you think about that? Good for what? Bad for what? • If bad, have you even tried other alternatives? How was it?
What to do when kids get bored	• When your kid would get bored normally? How long it would last? • How do you know your kid got bored? Did they have any different behaviors? • What would you do during this time? (Any activity?)
Frustrations and difficulties	• What's the biggest frustration of traveling with kids? • What difficulties you have ever met before? • If you were the driver, does it influence you for any aspect? • Is traveling with kids a tiring or difficult thing?
Thought about car traveling time	• Do you enjoy the time staying in car with your kid? • Do you think the time is also a part of trip? • Why you think it is? Why not?

4.2 Data Analysis: Affinity Diagramming

Affinity diagramming is used to analyze data collected from the interviews. I transcribed the interviews first, then extracted the key word for each and wrote them onto sticky notes. By moving the notes repeatedly, I attempted to categorize these findings into different groups for the further use. After several rounds of grouping, decomposing, and subgroupings, I organized the findings with six groups (as Table 2). First, behaviors of the children. Second, frustrations the parents met when traveling with children. Third, strategies parents have taken to entertain the children. Fourth, cognition of parents to travel with children. Fifth, preparation and plans for a car trip. And lastly,

the overall activities they do in the car. Details about the findings will be discussed in the next section.

Table 2: Results of affinity diagramming

Behavior of children	• Complaints about boredom • Making noise • Fights with other kids. Grabbing toys.
Frustrations	• Preparation takes too much time • Becoming distracted and impatient when children make noise • Picking up falling toys for children, making me carsick • Ipad is useful, but it might compromise the health of my eyes • Having to listen to the same songs children love to hear over and over again
Strategies	• Giving them food • Sleeping less the previous night • Stopping at a rest area and letting them run around
Cognition for road trip	• Enjoy getting together, good time to talk with kids (3) • Just commuting (1) • One- and two-hour constant periods of travel
Preparation and plan	• Take much more time • Many things must be prepared for children • Bring water and food • Allow them to bring toys and books
Activities during travel	• Sleep • Eating • Must stop at rest areas • Listen to audiobooks and music • Identifying car games • Make up stories • Ipad is the most useful for my children

4.3 Research Findings & User Requirements

After the analyses of interview data, I organized the findings and translated them into user requirements for the following design stages. They basically coincide with the results of a literature review. The parents mostly value the time spent with their children in the car, but all of them state that the experience is not completely pleasing. The children commonly make noises on the road when they get bored. Three of the interviewees assert that they have been distracted or anxious when their children don't behave well in the car. The other one parent explains that his children usually can be controlled by his wife, so overall experience is okay. However, if more than two children are in the car, they would lose their temper more easily because the children would fight with each other or grab other's toy. During this time, all parents have different strategies to make the children calm down. All of them agree that food is useful to keep their children calm, and digital devices are the most useful tools to entertain their children. But three of them state that they also worry about the children's eye health; so they limit the using time of digital devices for their children. Three of the interviewees agree that traveling with children is harder, especially for the preparation and planning part. They usually need to prepare the entertainment tools for their children before departure. The popular entertainment tools include audiobooks, music, videos, books, and children's favorite toys. They also play the verbal games in the car, such as I spy, car identifying game, counting, and so on.

Later, I generated the user requirements based on the findings. These requirements will be implemented in the design stages with the integration of other findings from literature reviews and competitive analyses.

User Requirements

- The system can't influence driving tasks and compromise driving safety.
- The system must provide a game environment for passengers in private cars.
- The system must allow multiple passengers (more than two, and they can be in different cars) to interact with one another.
- Users can collaborate with one another to achieve goals that the system sets up.
- The route, the car, the environment, and the landscapes users pass by will be involved in the game.
- The system includes an app and several pieces of objects for users to use.
- The users needn't stare at the screen.
- The value of family trips is emphasized.

4.4 User Experience & Behavior Modeling

Here I model the current experience and user behaviors by using personas and a journey map. Before starting the design phase, I find it useful to create these diagrams for the reference of following design decisions.

4.4.1 Personas

Personas are used to model the target users. In this project, I have two groups of target users. One is representing the parents, and the other targets the children.

The representative of parents (as Figure 5) usually sits in the front passenger seat and has to help the children. She and her husband often travel with their children during

the weekends. Before every car travel, she has to prepare food, toys, storybooks, some music her children favor and videos to make sure that they keep entertained. Because once they feel bored, they will start making noise and make her feel stressed and anxious. The most useful strategy to entertain her children is playing videos or mobile application games on digital devices. But she is also afraid of influencing the eye health of her children. Overall, she likes to travel with her children, but the experience sometimes makes her frustrated.

In the second persona (see Figure 6), the representative of children users is a 5 year-old boy. He usually travels with his parents and his younger brother. Before the travel, he would put his favorite toys into his backpack so that he can have something to do during the road trips. His younger brother often grabs his toys and make the toy falling onto the floor. He gets frustrated about this, because he can't pick it up by himself and his parents in the front seat are hard to do it for him too. He enjoys the time when his parents allow him to play digital games. The interactive games are interesting and attractive for him. He feels staying in the car for such a long time is very boring. He wants to know how much longer it takes to arrive to the destination.

Persona: Parents

Ann Young

Age: 35
Gender: Female
Location: California
Occupation: Accountant
# of kids: 2 (4y, 6y)
# of cars: 1
Major driver: No. Husband

Bio

Ann Young is a mother of two boys. She also has a full-time job as an accountant. She and her family live in California and they usually travel to some national parks nearby during weekends. Shayan, her husband is usually the driver and Ann sits in the front passenger seat when two boys in the back seat. They usually take a rest after one-hour driving to let the two boys move their bodies and get tired so that they would be easy to fall asleep in the car. Ann has low tolerance for noise, but her two boys often fight with each other or even scream and cry during the trip, especially when they have nothing to do. Therefore, Ann would prepare some toys, snacks, audiobooks, DVD and the most important, tablet for her two boys in case they would get bored and become impatient to stay in the car.

Goals

- Make her babies enjoy the traveling time in car and not always feel bored.
- Keep the whole traveling time relaxing and not noisy.
- Let her husband focus on driving and not influence by the two boys.
- Prepare easily for travelling with kids.

Frustrations

- If her boys have nothing to do, they would become impatient and noisy. And she would start feeling stressed and distracted too.
- She doesn't want her kids staring at the tablet during the trip while that's the most useful way to keep them quiet and entertained.

Figure 5: Persona to represent parents

Persona: Children

Ryder James

Age: 5
Gender: Male
Location: California
Education: Preschool
IT Skill: Great

Bio

Ryder is an energetic boy. He likes outdoor activities, such as sports, racing cars and also traveling, but he doesn't really enjoy the time in car, especially when he can't figure out what to do. Eating, watching video or playing games on the tablet would make him feel much better. He would also pack up his toys by himself before the trip. He has a younger brother, Ryan. He loves Ryan but Ryan always disturb him while he is watching video or playing game on the tablet. And then they would start fighting with each other until their mom stop them. He is a fan of a variety of cars. He is able to identify different brands of car on the road. That is also a game they play together during the car travels.

Goals

- Find something to do in the travelling time.
- Hope his younger brother not to grab his toys.
- Want to know what it is going on or be engaged during the car travels.

Frustrations

- He feels bad to stay inside the car too long when he doesn't feel sleepy.
- He wants to arrive the destination quickly.
- His brother always tries to annoy him.

Favorite toys & games

Lego, Cars, Robots, Mobile games, Weapons, Cards, Story books, Children's songs, Tablet and Balls

Figure 6: Persona to represent children

4.4.2 User Journey Map

The user journey map (see Figure 7) illustrates the tasks users will do in the current car travel experience. The user journey can be divided into three parts: 1. Preparation, 2. During travel, and 3. Arrival. The first row in colors shows the activities and behaviors of parents, and the second row demonstrates those of children. The text boxes are quotations from the interviews, and the texts with flashing marks are the insights or potentials for design improvements. Through this user journey map, we can learn that the preparation process is really complex and time-consuming. And during car travel, parents usually entertain their children with prepared materials. They try to plan the schedule for them, such as the time to go to the rest area, the time to sleep, the time limit for watching digital devices, and so on. Some behaviors of children also influence how the parents drive. Lastly, when they arrive, they just leave, and nothing is left behind and stored.
These useful insights also inspire the design development in the later stages.

4.5 Summary

In this chapter, I review the process of user researches and the insights obtained from them. With the information, I have a clear image about the experience of the car trip the users are going through and the expectations that could make their experience better.

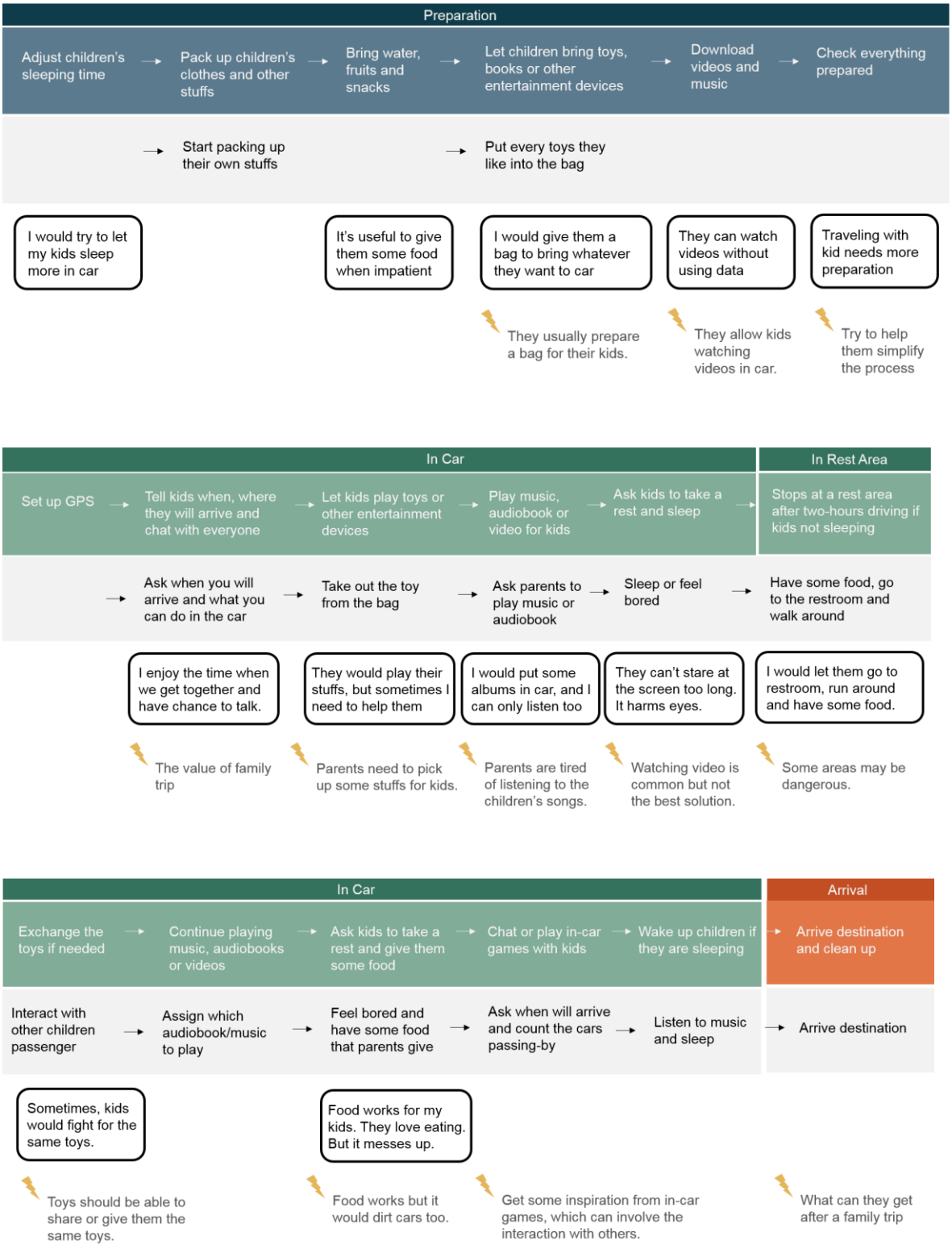


Figure 7: User journey map

CHAPTER 5 DESIGN PROCESS

The design process is always iterative and will probably never end. In this chapter, I mainly focus on the development of the first generation of design. The further evaluations and refinements of the final design, which has the nearly finalized structure of the whole system, will be introduced in the next chapter. Because the project is not built on the existing framework and making further improvement; instead, this is a brand new system and aims to create a new direction of the in-car entertainment system. The first design framework is especially important and difficult to create. Once the design framework is generated, the following design movement would be easier to be made. Therefore in this chapter, besides the introduction of design detail, the iterations of framework creation will be emphasized.

5.1 Identified Problems & Design Objectives

Here I would like to highlight the identified problems and design objectives before the introduction to the design phases. In the research stages, I conducted literature reviews, user research, and competitive analyses to find and analyze the problems iteratively from different perspectives and concluded the design objectives based on these research findings. Through literature reviews, I attempted to understand the users and the problems they face from the perspectives of parents and children. The reviews also allowed me to find the best angle to target this topic, which is valuable to set the design objectives. After deciding the topic and having a brief understanding about the users and

problem domain, I reached the real users to deeply acknowledge their frustrations with current experiences and the expectations.

Then with all the findings on hand, I analyzed the existing products that are currently used to relieve their pains and found the gap between user expectations and their current experiences for the references of final design objectives and directions. The identified problems and targeted design objectives are discussed below.

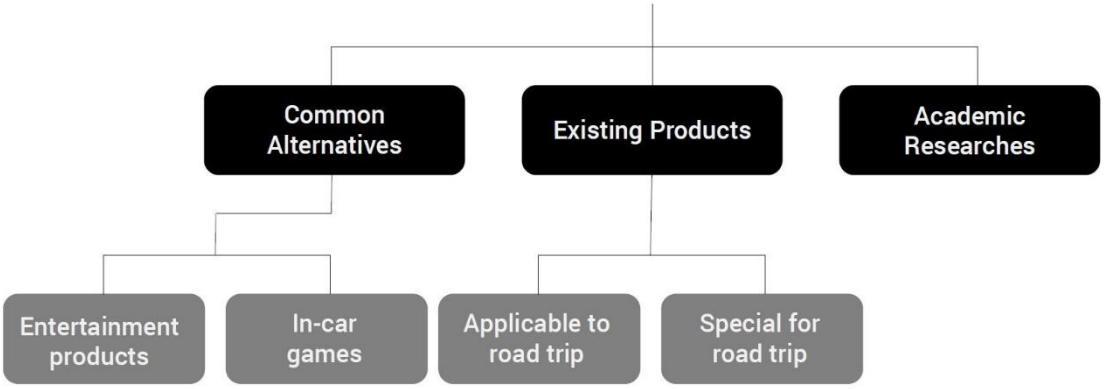
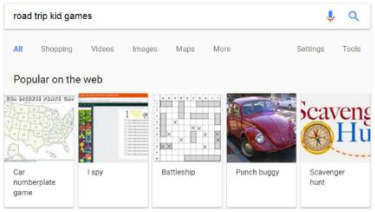


Figure 8: Structure of competitive analysis

Table 3: Results of competitive analysis

		Pros	Cons
Entertainment products		• They may be children's favorites • Easy to prepare	• No connection with trip • Some of them may be difficult to play in car • Some of them may affect eyes health • No too much variation
In-car games		• Good interaction with other members • Not necessary to look at screen • No product needed	• Only few are suitable for children • Hard to keep children interested and focused • Needing someone who knows how to play and lead • No connection with road trip
Applicable to road trip		• Easily getting children interested • A large variety • Able to be played in one device	• Children need to stare at the screen • Some of them may cause motion sickness • No connection with road trip
Special for road trip		• Utilizing the elements on the road • Many people can participate • Collecting the game which can be played in the car	• Not really connected to the car travel • Needing someone who knows how to play and lead

Traveling with children, overall, is not a pleasant experience for many parents (Daily Mail, 2011). Because children get bored more easily than adults, and if they can't find something to do to conquer the boredom during that period, they will, start making noises, crying, being anxious and even distracting the driver. Parents have different strategies to keep their children entertained to go through such troublesome times. However, the unpleasant experience is still not improving with these strategies, and they even cause other problems. Here are the problems with the current experience.

- **Lack of resources:** Parents have no idea how to entertain their children during a car trip.
- **Too much preparation:** Preparation for car trips has been complex, and parents still need to bring many toys or prepare audios in advance for their children.
- **Health compromising:** They worry about compromising eye health if allowing their children to use digital devices for a long time, but many parents express game applications or playing videos on the digital devices is the most efficient and effective way to keep their children entertained and be calm.
- **Limited space:** Car space is limited, and the children are usually stuck in child safety seats. Thus the activity they can do or the toys they can play with are also limited. Some parents complain that some toys would be easy to fall out of reach from the children's grasp and their children would start scream until the toy is picked up (Wilfinger et al., 2011).

To design a new system, I not only aim to solve the identified problems, but I also hope to create a new experience that is more meaningful and closer to user goals. After the extensive research in the early stages, I also found the valuable points that can make the entire experience more colorful and valuable.

- **Connection to environment**: The world outside a car is beautiful. But Car passengers usually ignore it. How can I make the environment become one of the key elements of the system?
- **Space for memory storage:** They cherish the time spending with their children in a car, but there is nothing they can keep. What can be left after a family trip?

5.2 Brainstorming & Bodystorming

With these design objectives, I started brainstorming for the solutions. Bodystorming (Schleicher, Jones, & Kachur, 2010) was also used to ideate with the in-person experience. The goal of this stage is to find any possibility of the system. Therefore the ideas could be very conceptual and creative. The feasibility of the technology would be considered in the later stages and during the development. I first sketched the ideas on the notebook and collected the final findings with the sticky notes, then organized ideas in the method of affinity diagramming. The result is shown on the picture below (as Figure 9).

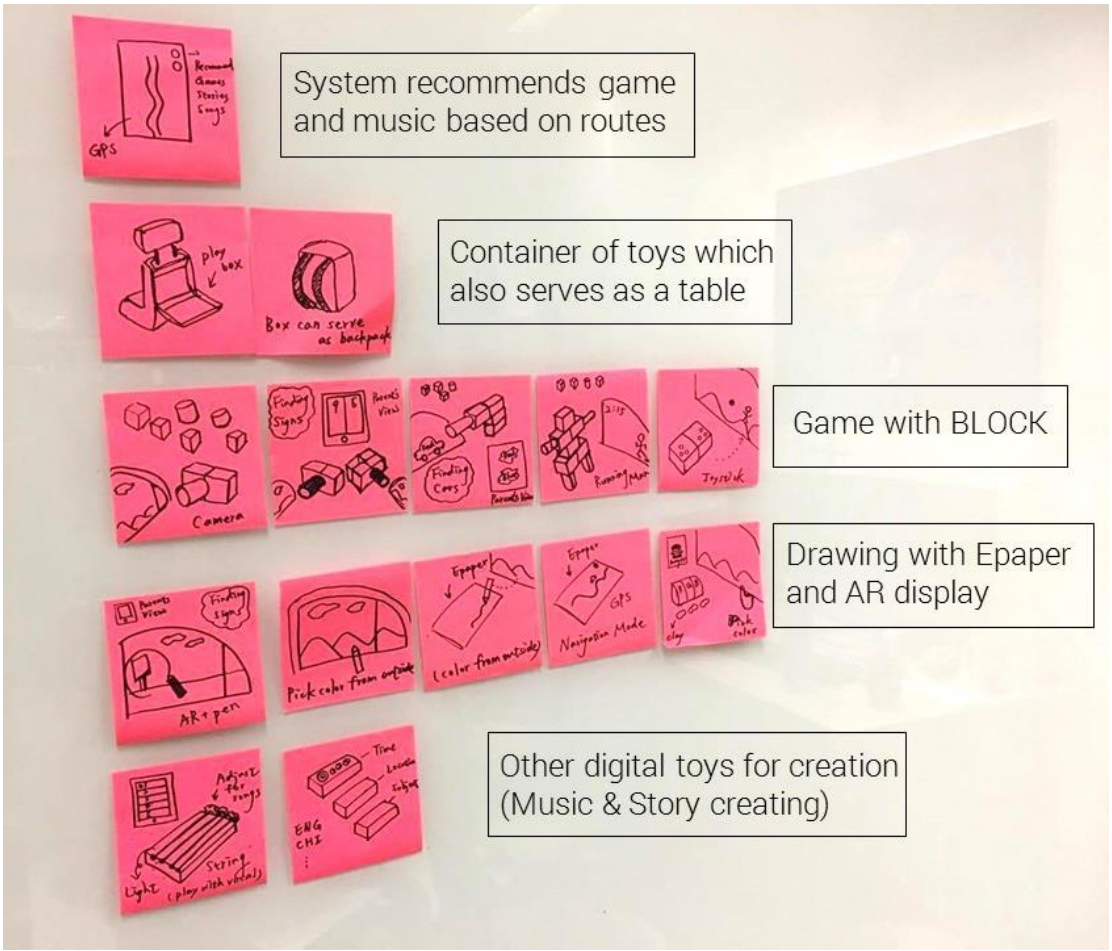


Figure 9: Categorized ideas by using affinity diagramming

1. **System recommends games and music based on routes**

   This idea is using GPS technology to tailor an entertainment plan for users. GPS technology can detect the road conditions, routing, and so on. With this information, the system can recommend games or music based on user needs and routes. For example, when users are close to a destination, the system can provide energetic music to wake up the children and keep them excited. Or according to the road conditions, such as a traffic jam or construction, it can suggest different games to help the users go through the hard time.

2. **Container of toys that also serves as a table**

   This concept is generated based on user interviews. Several interviewees explained that they usually prepare a backpack for the children and let the children pack their own toys in it. Therefore I was thinking what if the bad serves as a part of car component.

3. **Game with blocks**

   Toy blocks are good for children to develop their creativity. They could also be transformative with many different ways to play. In a limited space, children have little chance to bring too many toys along. Thus making a toy multifunctional is important, but it might also be challenging.

4. **Drawing with E-paper and AR display**

   During a road trip, the family will pass by many scenes or spots, but they usually don’t pay too much attention to them. This should be a valuable part of a road trip; so in this idea I tried to connect users to the environment, and the AR display could a good media.

5. **Other digital toys to develop creativity**

   Here are several concepts about creativity development toys. They are all related to activities that children are currently prone to do in a car. And what I tried to design here is making the activities more systematic and suitable for the car environment.

All of the above ideas are based on the research results and personal experience during a car travel bodystorming. After the ideation, I did an overall analysis on each idea and decided on the final direction, which is a system combining several design concepts together (as Figure 10).

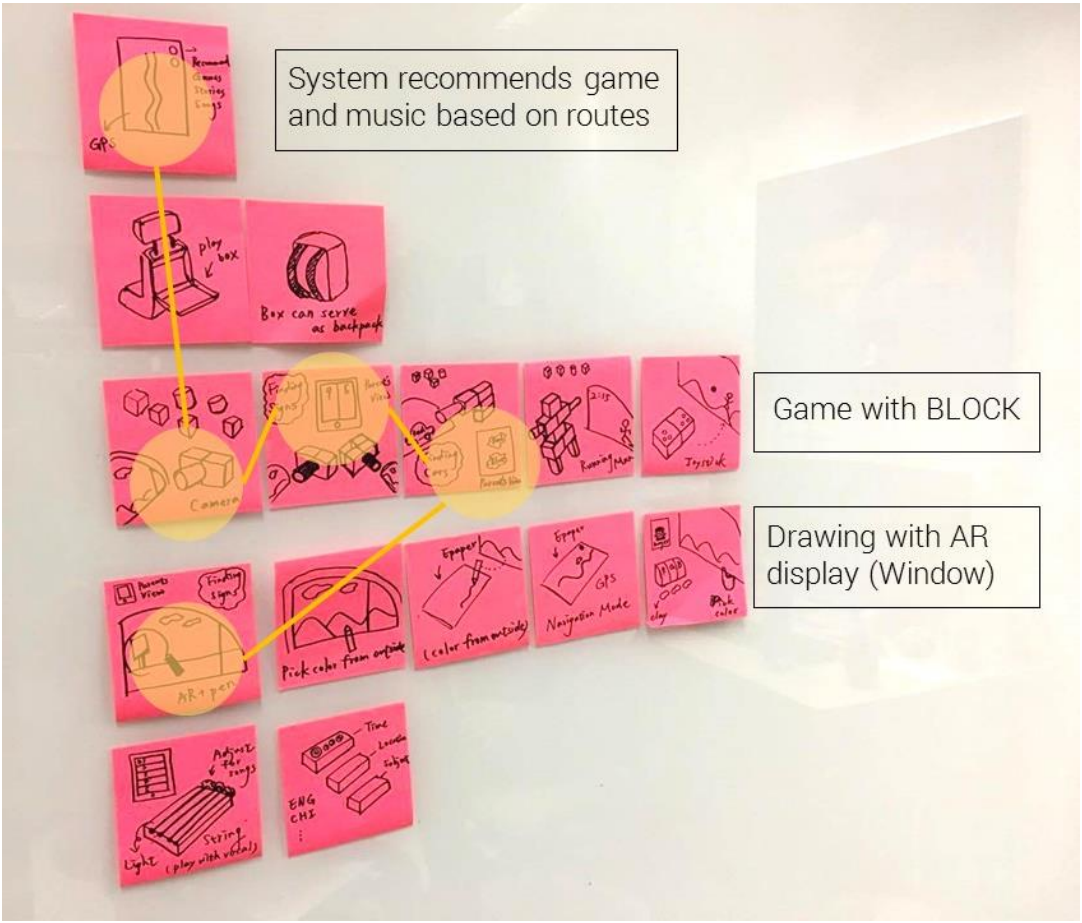


Figure 10: Final design direction

As shown in Figure 10, the system will include an application that can recommend games and music. It will also plan travels for the users, with a multifunctional block on the children's side as the major toy and an AR display embedded on the car window to enrich the travel experience.

5.3 HTA & Concept Development

With the design direction generated from the first stage, HTA, Hierarchy Task Analysis, is used to further frame the design structure of the application. By analyzing the tasks users can conduct on the first finalized design direction, the entire structure may be examined thoroughly. This is helpful for me to identify the problems of the design direction at the very beginning before I develop the details.

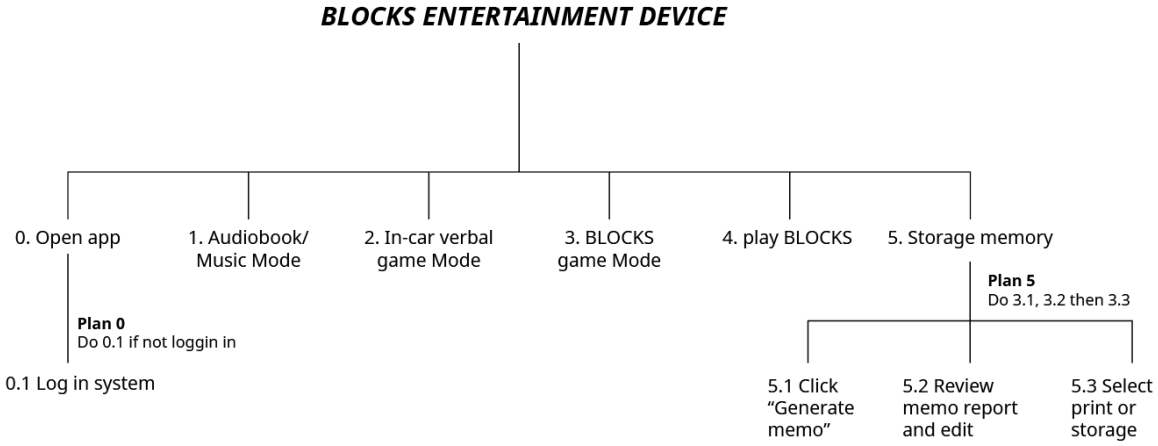


Figure 11: HTA chart- Overall structure

Figure 11 demonstrates a rough idea about how the users can play with the application. The details about task 1-3 are shown on Figure 12, Figure 13 and Figure 14. This is the first generation about the structure of the application. Here I divided the entertainment that users can take during a car travel into three parts and created a space for them to keep memories. Through this analysis, I found two major problems in this design.

First, the GPS-oriented design could not be easily discovered by the users in this system. The whole system was just like a game platform, which is not what I aim to design. Second, users have a problem with planning, but in this design, the problem isn't well solved. Therefore in the final version of design, I change the hierarchy and make the planning function at the topmost layer as one of the major features. The details about the information architecture will be introduced in the next section.

For the concept development of the physical blocks, I first came up with the ideas about the transformed shapes based on the games that users currently play and that have the potential to be integrated with the toy blocks. In the first version, I designed the cubes to be assembled into different shapes with the few components, allowing children to bring the fewest possible blocks to the most possible shapes. Although every cube is the same, different shapes may still be created with the well-designed components on each side of the cube. This freedom also allows children to create the shapes in the way they like. The set of tools includes four cubes and one camera column. The 3D models are shown on Figure 15.

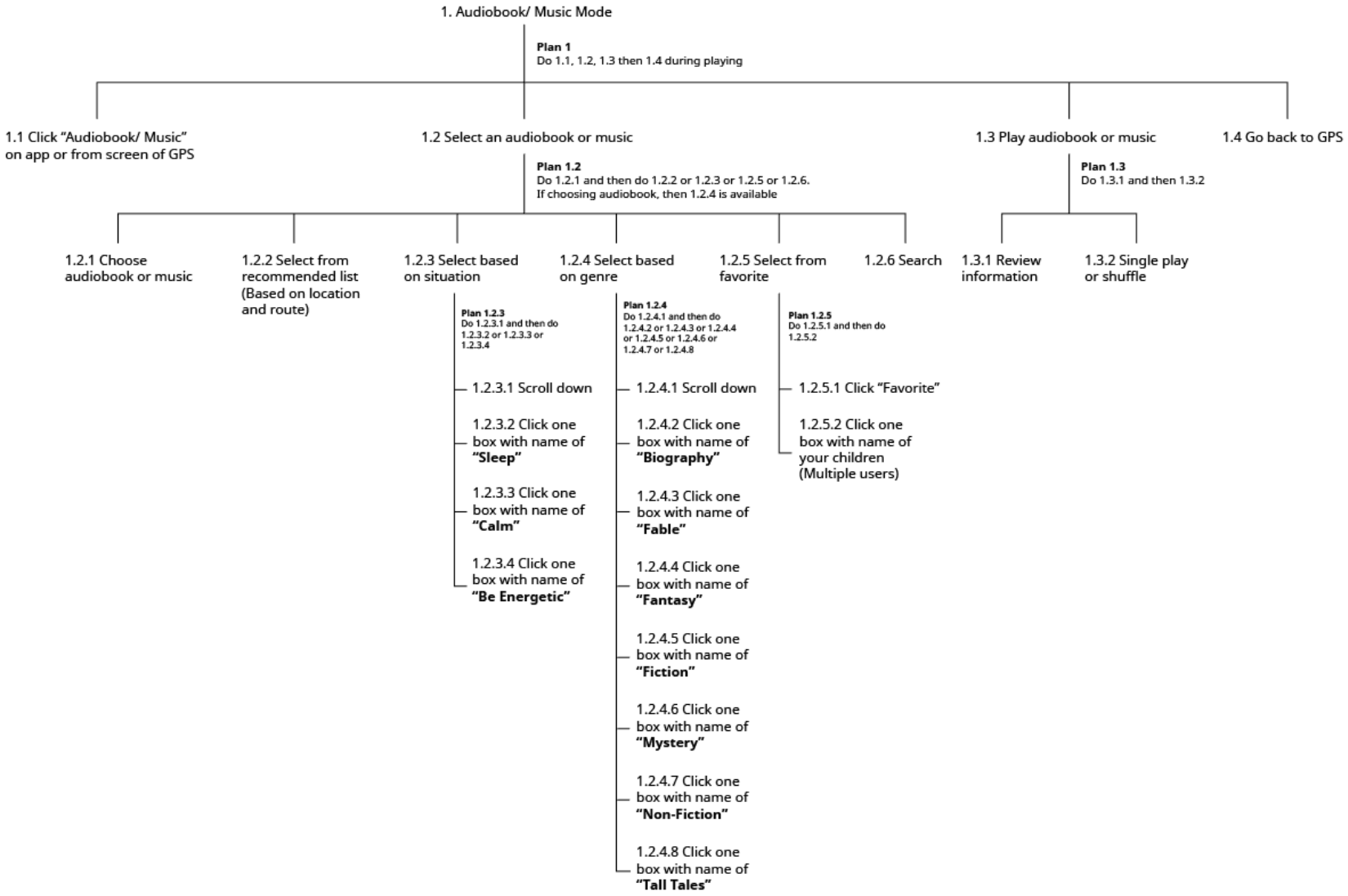


Figure 12: HTA chart- Task 1

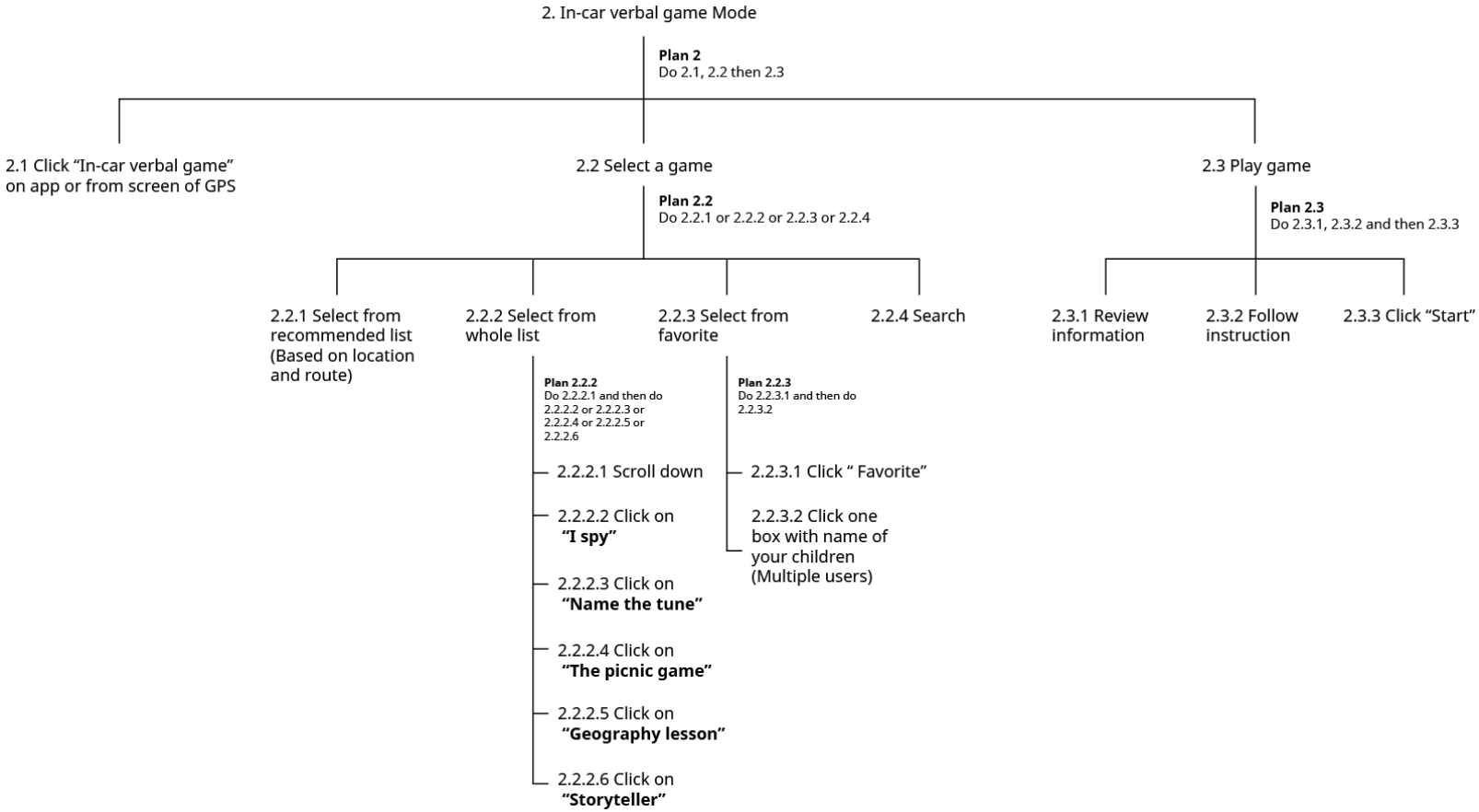


Figure 13: HTA chart- Task 2

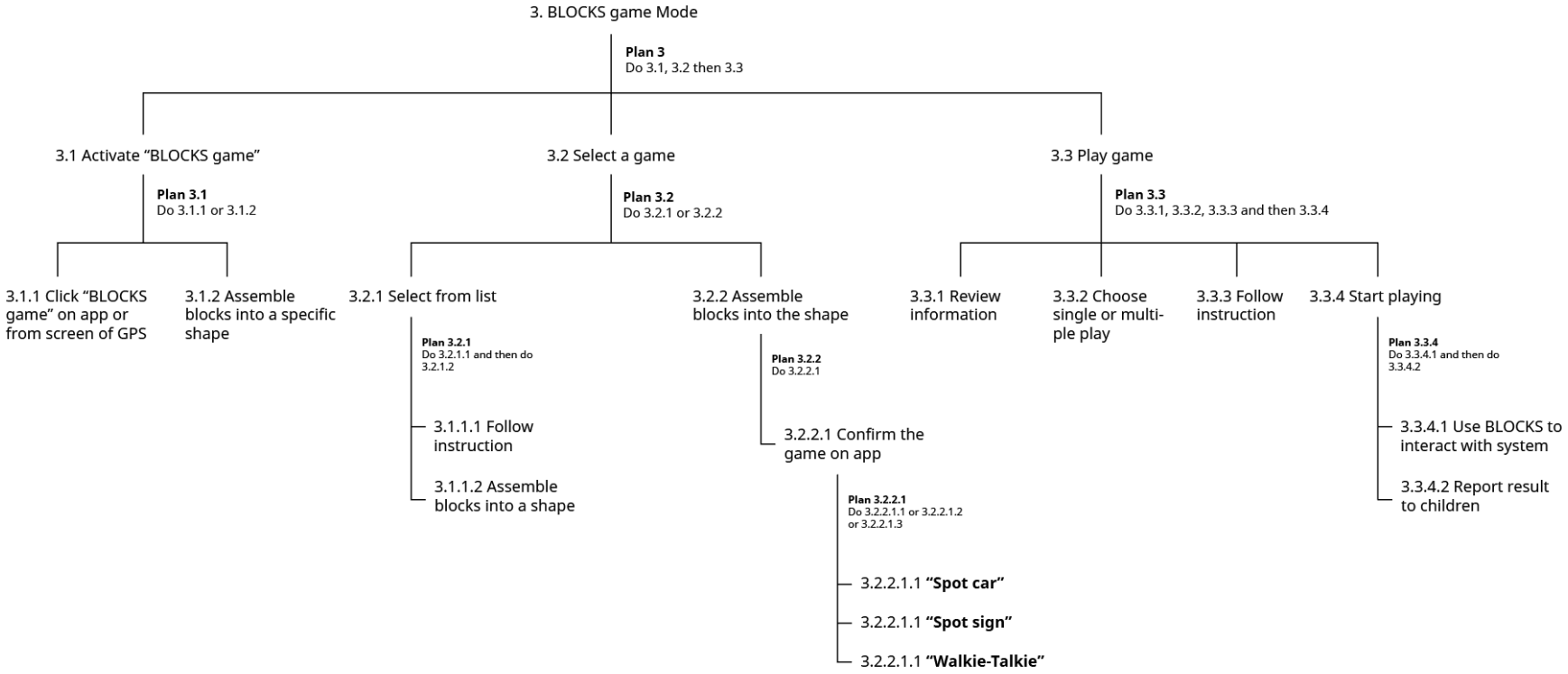


Figure 14: HTA chart- Task 3

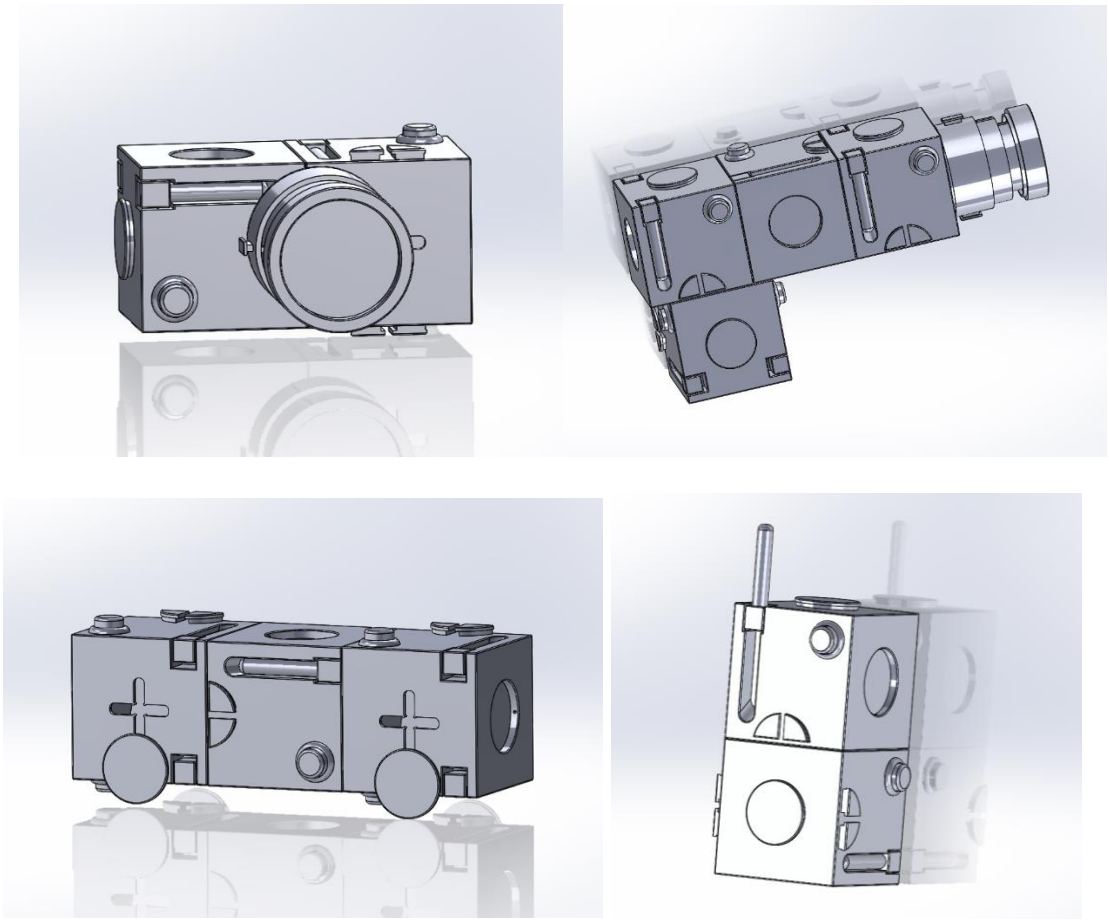


Figure 15: 3D models of the first version of cubes

5.4 Prototyping & Refinement

The prototyping process in this section puts more emphasis on the iterations of a physical product. From 3D modeling to 3D printing, the blocks went through several rounds of building and refining to make sure that each could satisfactorily fulfill the design functions.

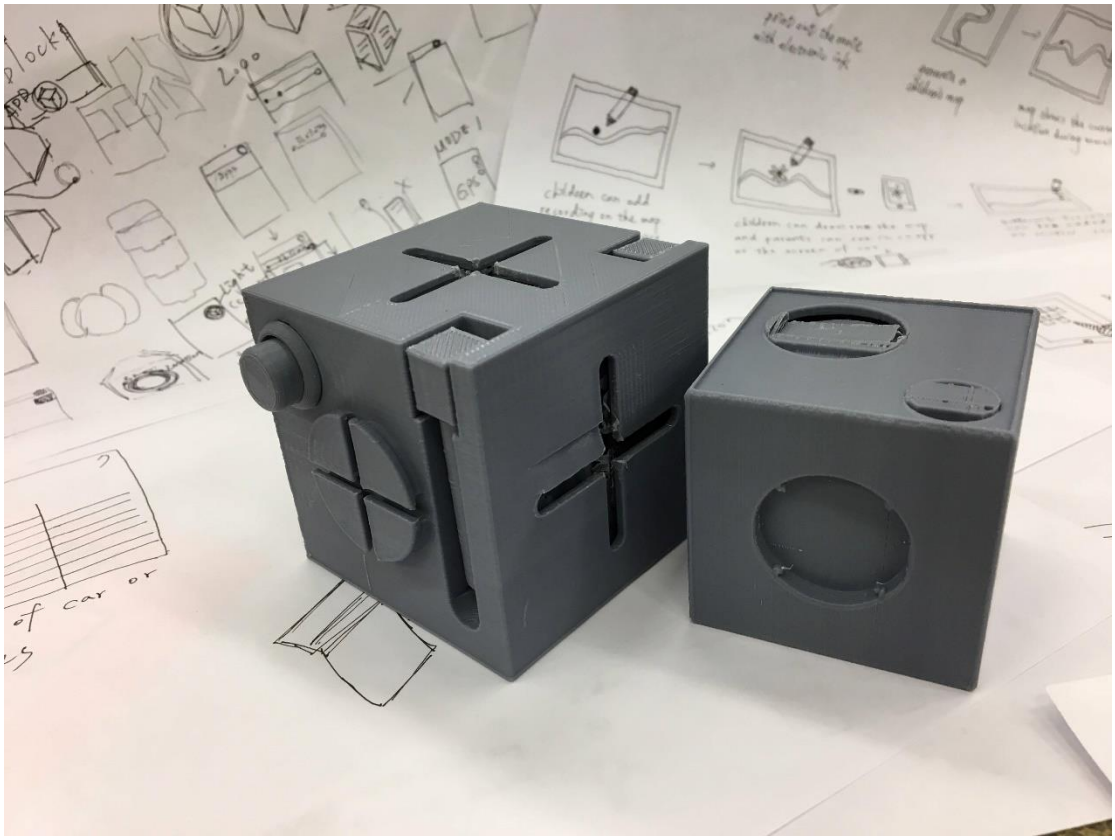


Figure 16: 3D printing test of the first version of cubes

As learned from Figure 16, the very first version of a 3D printed cube (the left one) was too large for children. Its size was 2.5” x 2.5” x 2.5”. Hence, I shrink the size to 2” x 2” x 2” for the following versions.

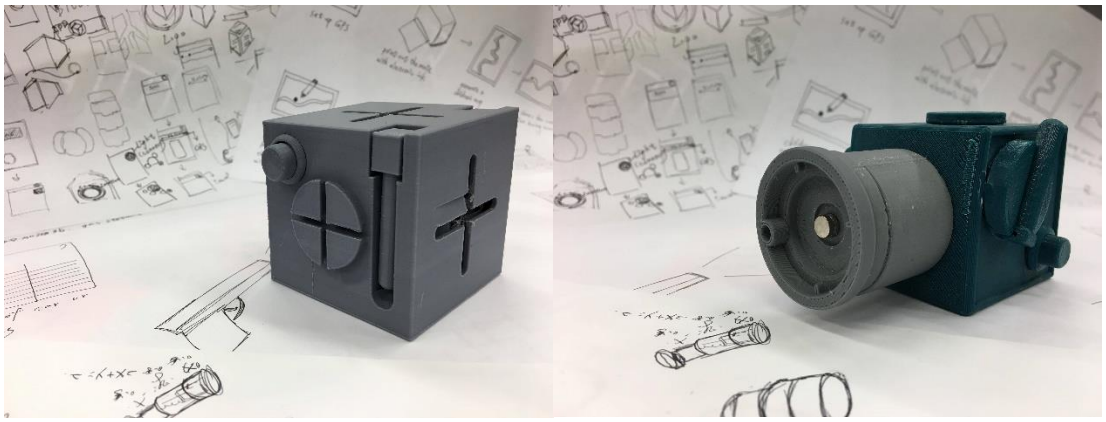


Figure 17: Variation of the cubes

Figure 17 continued

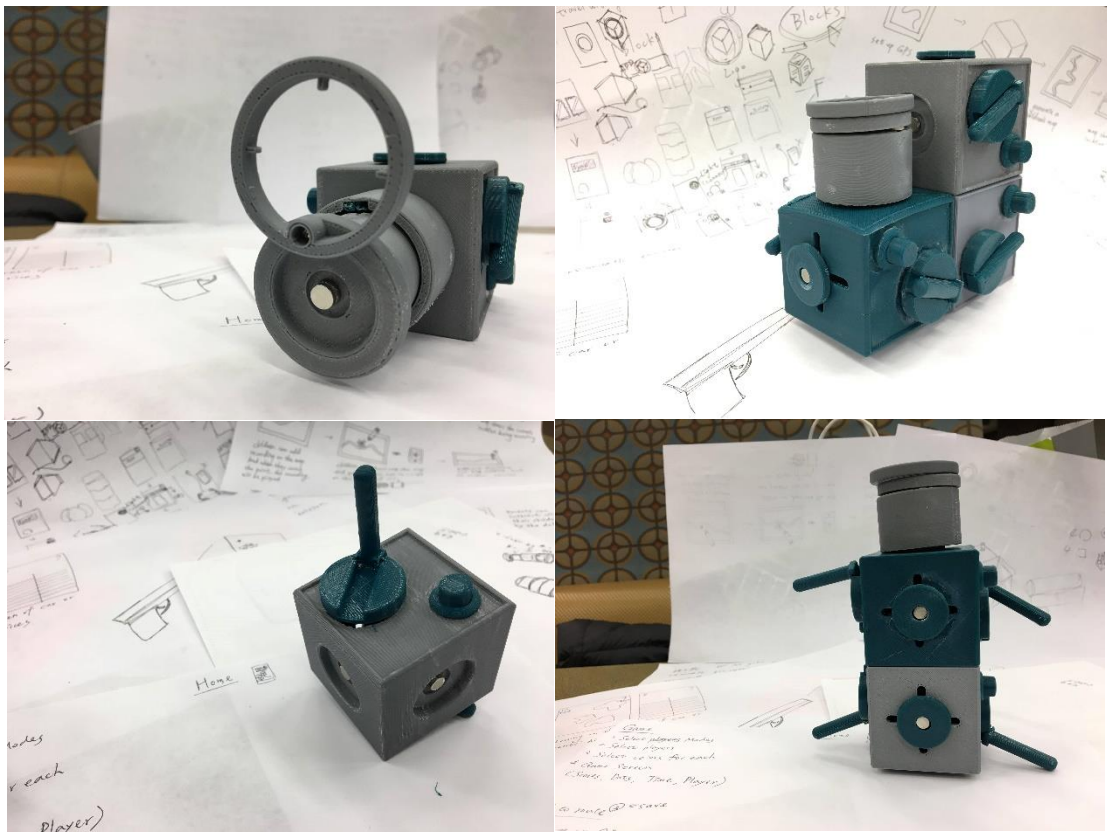


Figure 17 shows the variation of these cubes. Each component is movable and transformable. The electric components can be installed inside the cube, allowing the cubes to connect with the digital application. The digital application on the parent's side can detect activity on the children's side with the cubes and suggests the games based on the current shapes of the blocks. This design aimed to create the variation of the toys with the few units to entertain children in a limited car space. However, after an informal testing, I found that too many pieces remained for children to play in the car, and the designs on the each side of cube also caused much confuse; so I started thinking the possibility of a multifunctional block. Several multifunctional blocks are in the existing market, and one of the famous ones is Cubebot, a product of Areaware (see Figure 19). It

is a wooden robot toy with elastic-band muscles and can be positioned into dozens of poses and folded back to form a perfect cube. Besides, I also found a similar product of 3D Central (see Figure 19). It is a robot cube made of 3D printing materials. I edited the 3D models based on the frame and mechanisms of the product to fit the concept of my design. The final model is an adaption of this product.

Figure 18: Cubebot by Areaware

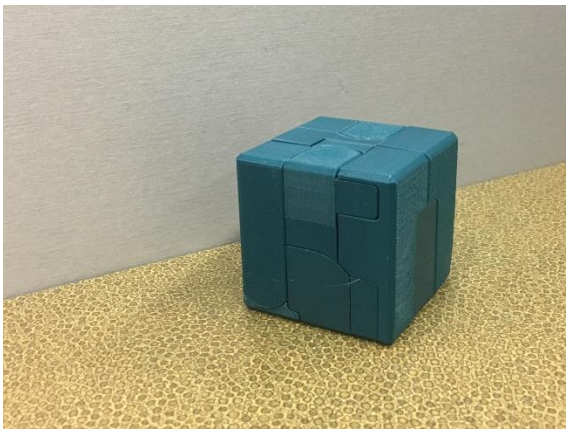


Figure 19: 3D printed toy of 3DCentral,

The pictures below (see Figure 20 & Figure 21) show the evolution of the physical block, from making it a cuboid, adding a dent to imitate the lens of camera, to embedding the button as the source of input for interactive games in the final design.

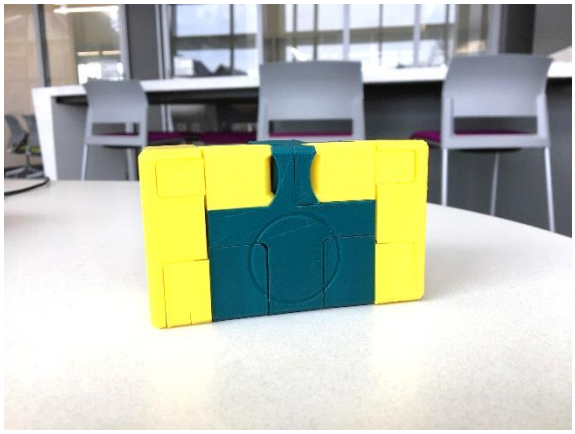


Figure 20: Working models of the final design

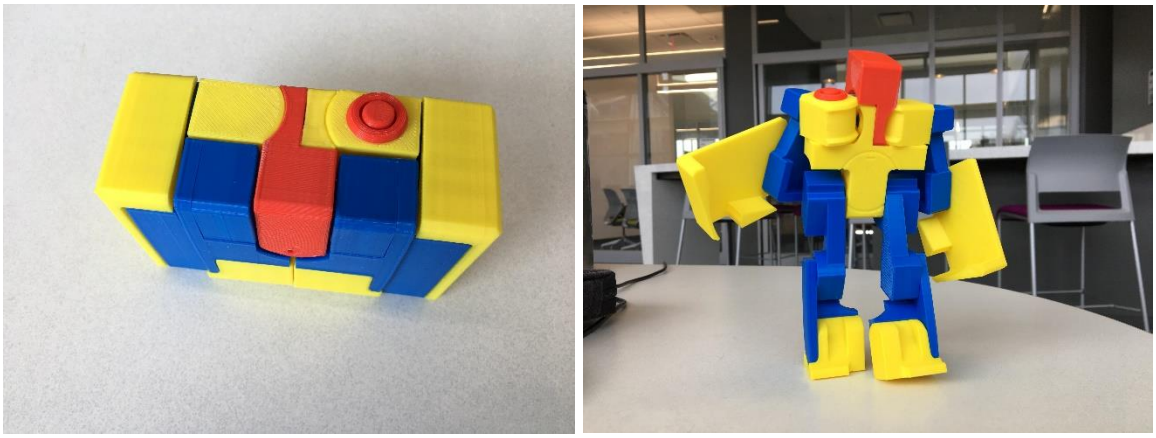


Figure 21: Mockups of the final design

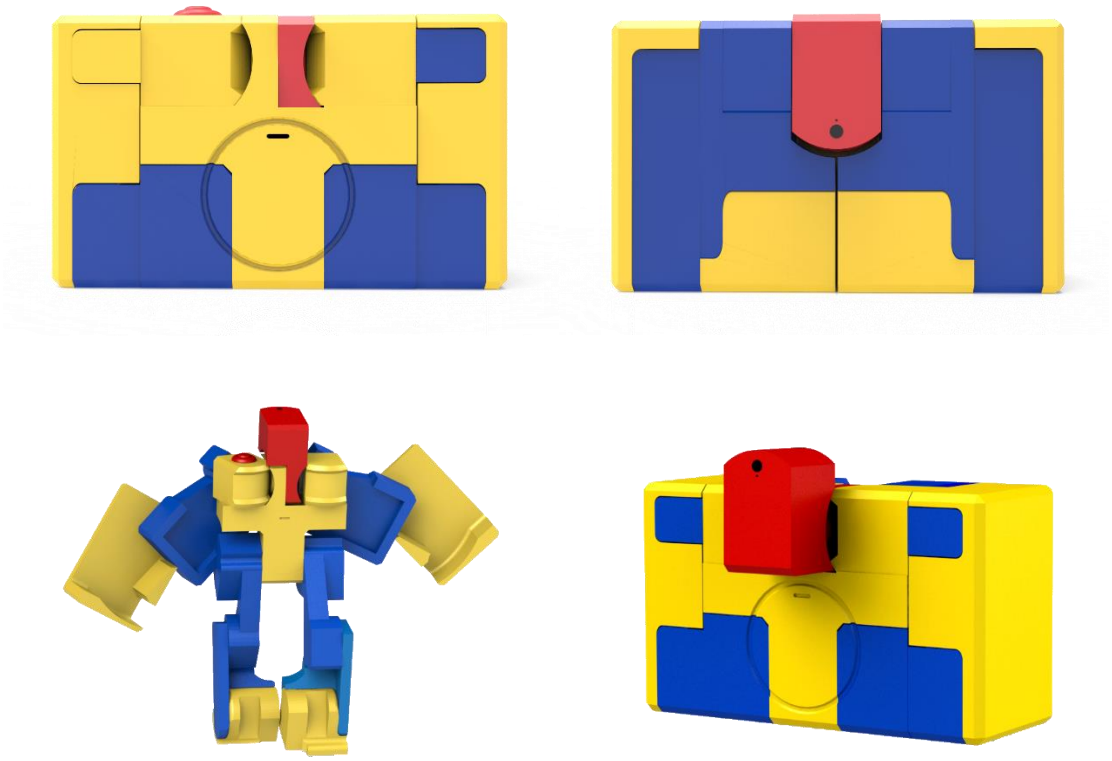


Figure 22: 3D models of BlokCar

5.5 Information Architecture & Wireframing

After building the design framework, I now have a clear image of what to do next for the design details. For the digital interface, the first thing is to map the information architecture, which helps me to review all the functions that should be included in the application before I draw the wireframes.

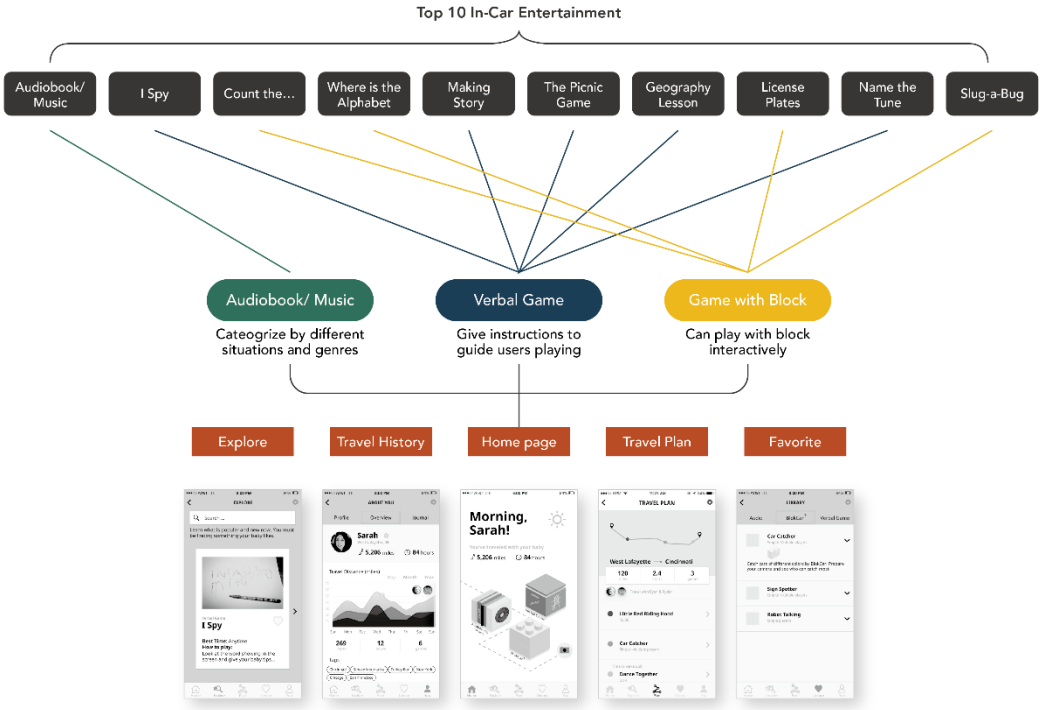


Figure 23: Top ten entertainments categorized into three groups

At the beginning, I categorized the top ten in-car entertainments into three groups: 1. Audiobook/ Music; 2. Verbal Game; 3. Game with Blocks (Figure 23). Audiobook/ Music includes any kind of audio sources that parents currently play to entertain their children. The most common types include storybooks, children's music, and so on. Verbal Game collects the popular games that can be played with no materials. Consider I

Spy for example, a game asking the host to keep a word in mind and let other participants guess what the word is. The host can provide hints for the participants. The first one to guess the right word wins. This kind of game is easy to play in the car because it doesn't need users to prepare and stare at anything. They can be played only through words.

Lastly, games with block. Games with the interactive block are adapted from the top activities in the car based on an interview and research results. The integration of the mobile application and the interactive block can enrich the game experience and create a bond between parents and children. For example, the system can make a recording and allow parents to view the game result on the mobile application.

Afterward, I reorganized the information architecture based on findings from HTA (Hierarchy Task Analysis). As mentioned in section 5.3, the planning function was hidden in the previous flow design. In the current version, I place the planning function at the topmost hierarchy to make it clear to users. So the collections of three categories of entertainment are then included in another tab at the same level of the planning function. It is also the default landing page when a user enters this application. According to the research, parents usually prepare the music, audiobooks, toys, and other things for the children in advance; thus the place to save these children favorites is a must-have. This is the third tab at the first hierarchy.

Fourth, the space to keep memories. As discussed in previous sections, one design objective is to create a space for users to keep their memories. And also because its importance, I also put it at the first level to allow users to easily check every time.

And last, the fifth tab in the first level- Explore. This function was inside the three categories of entertainment of the first version of information architecture. But in this

version, I collect the three entertainments and put them into one tab, which means that if I still put the exploration function in the collections, the exploration function will be placed more deeply. It would lose the meaning and features. The exploration function aims to suggest the new discovery and the trending items to users. It also meets the needs of a group of users who would prefer to try new things. For users of this kind, they need only to review the suggested entertainments a couple times a week and keep them in the library for later use. Here are the introductions to the functions at the first hierarchy.

After having the overall structure, I started to translate the concepts onto screens. The wire frames perfectly visualize the concepts, which enables me to easily examine the whole system and make improvements. During the process, I discovered several problematic flows and missing parts in this design. Once I found the problems, I would go back to refine the information architecture again. The entire process is iterative and aims to continue refining the final design.

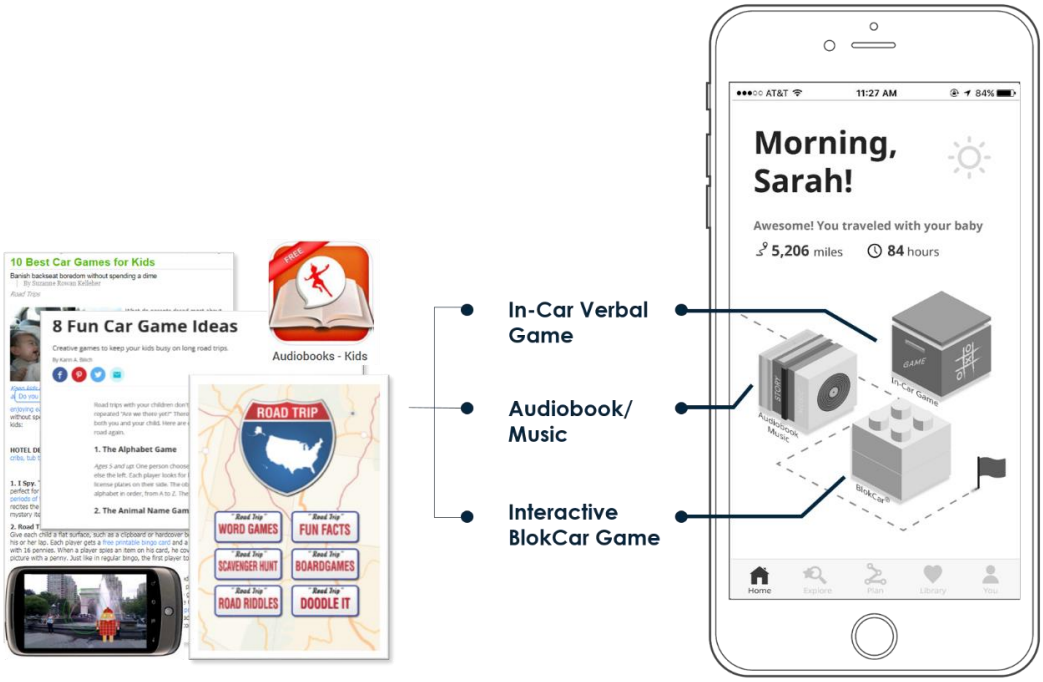


Figure 24: Home page (wireframe)

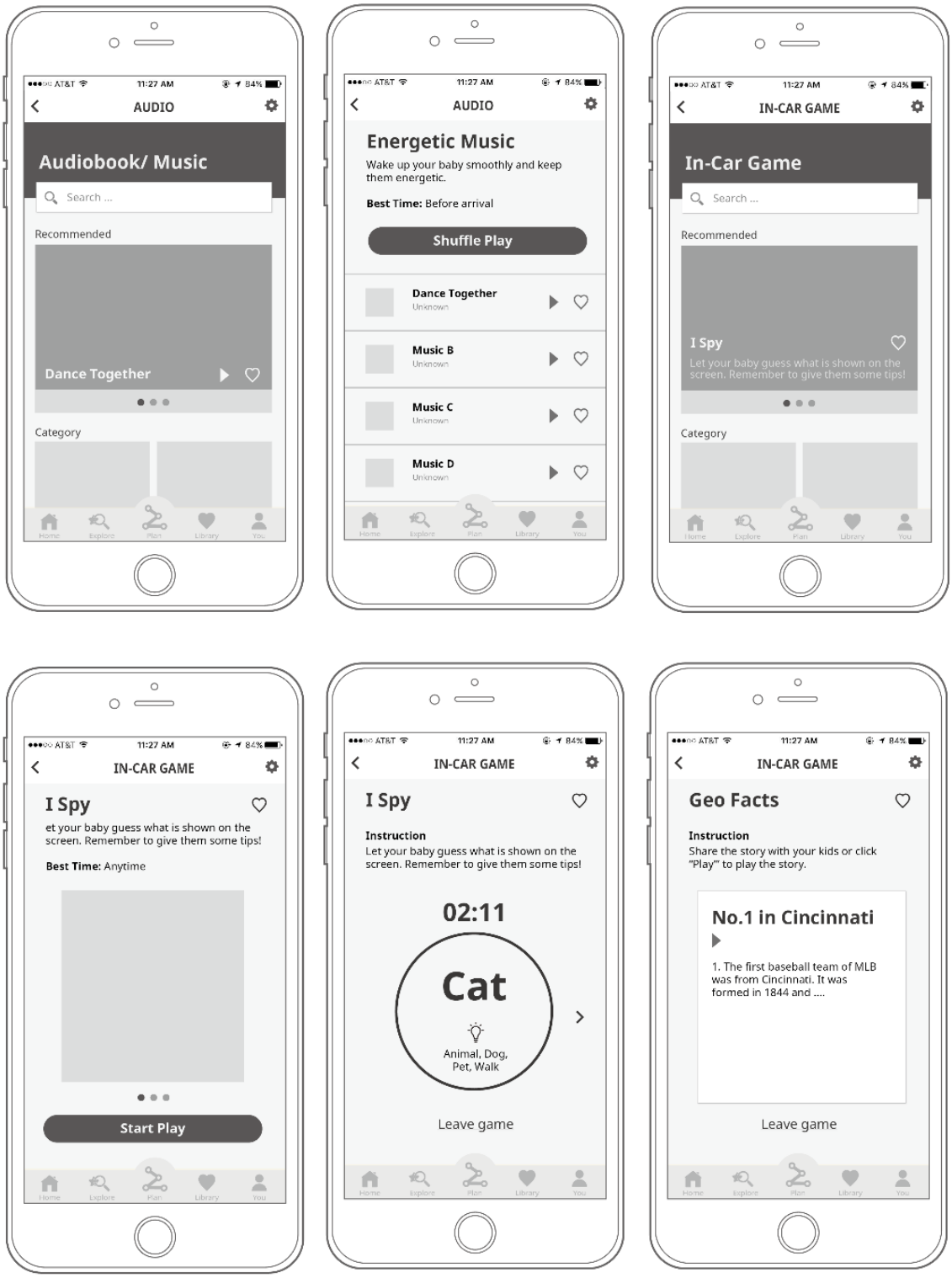


Figure 25: Entertainment collection and game screens (wireframe)

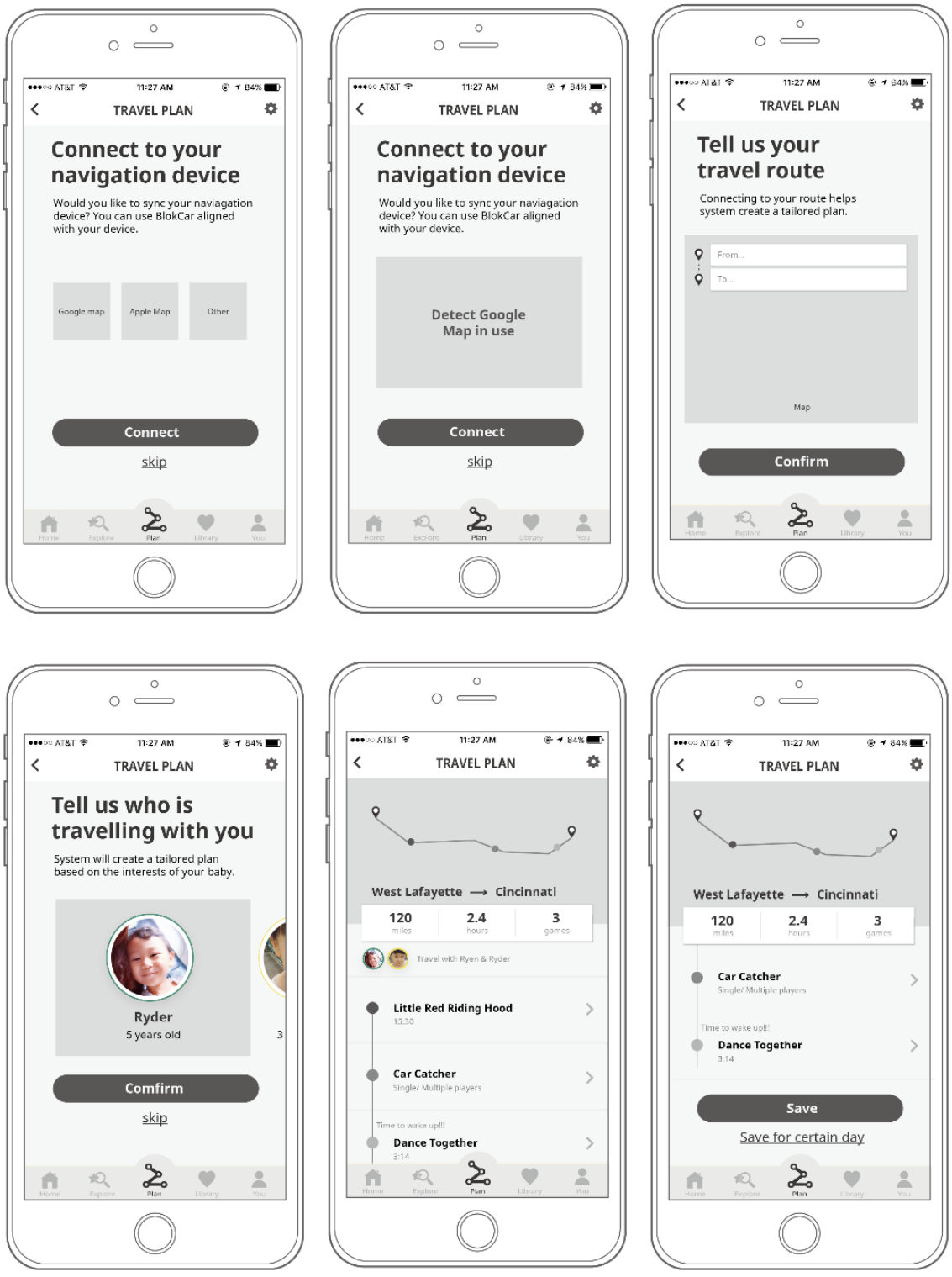


Figure 26: Travel plan with entertainments (wireframe)

Figure 27: Library for favorite items (wireframe)

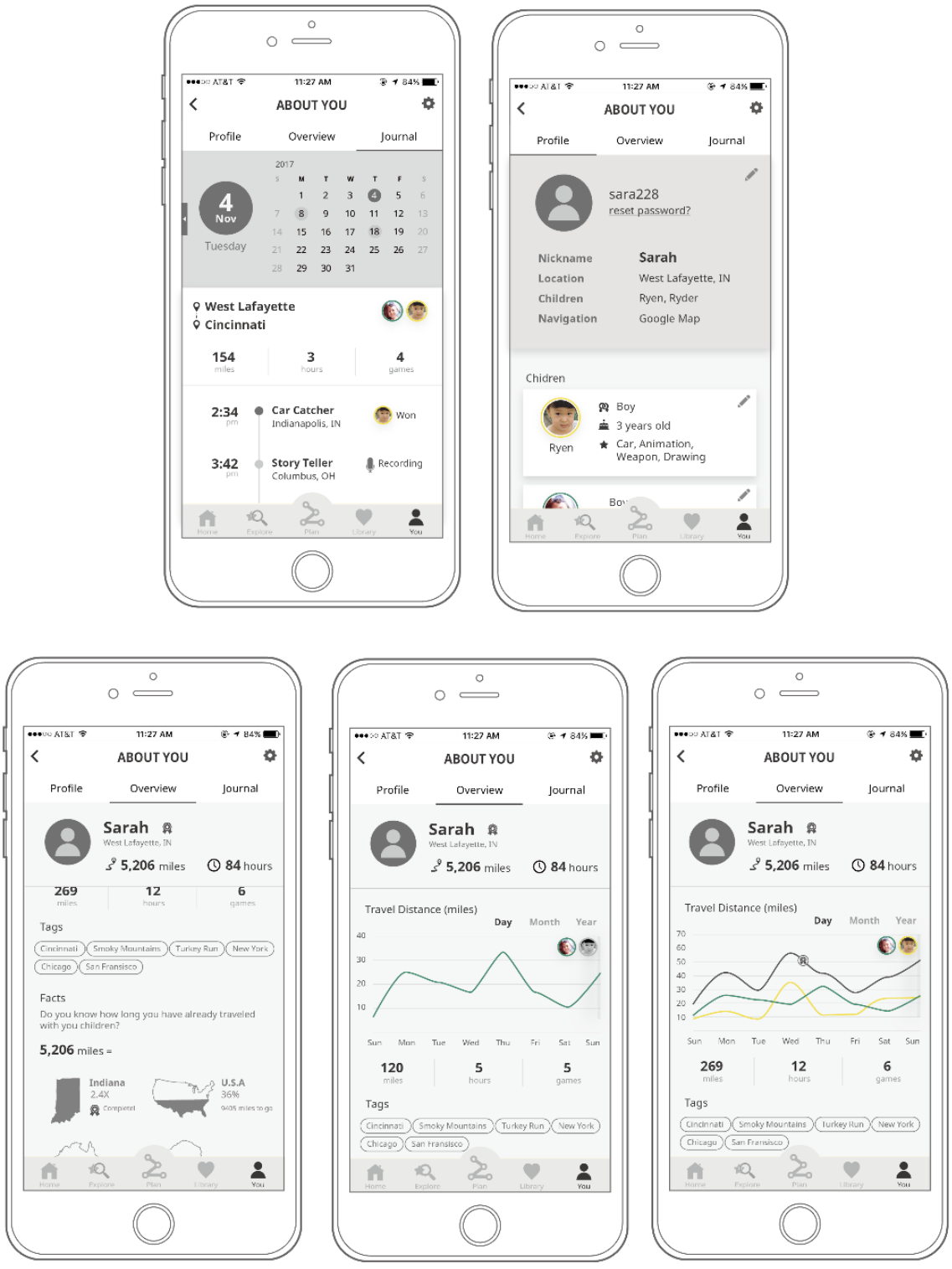


Figure 28: Travel history & memorable data (wireframe)

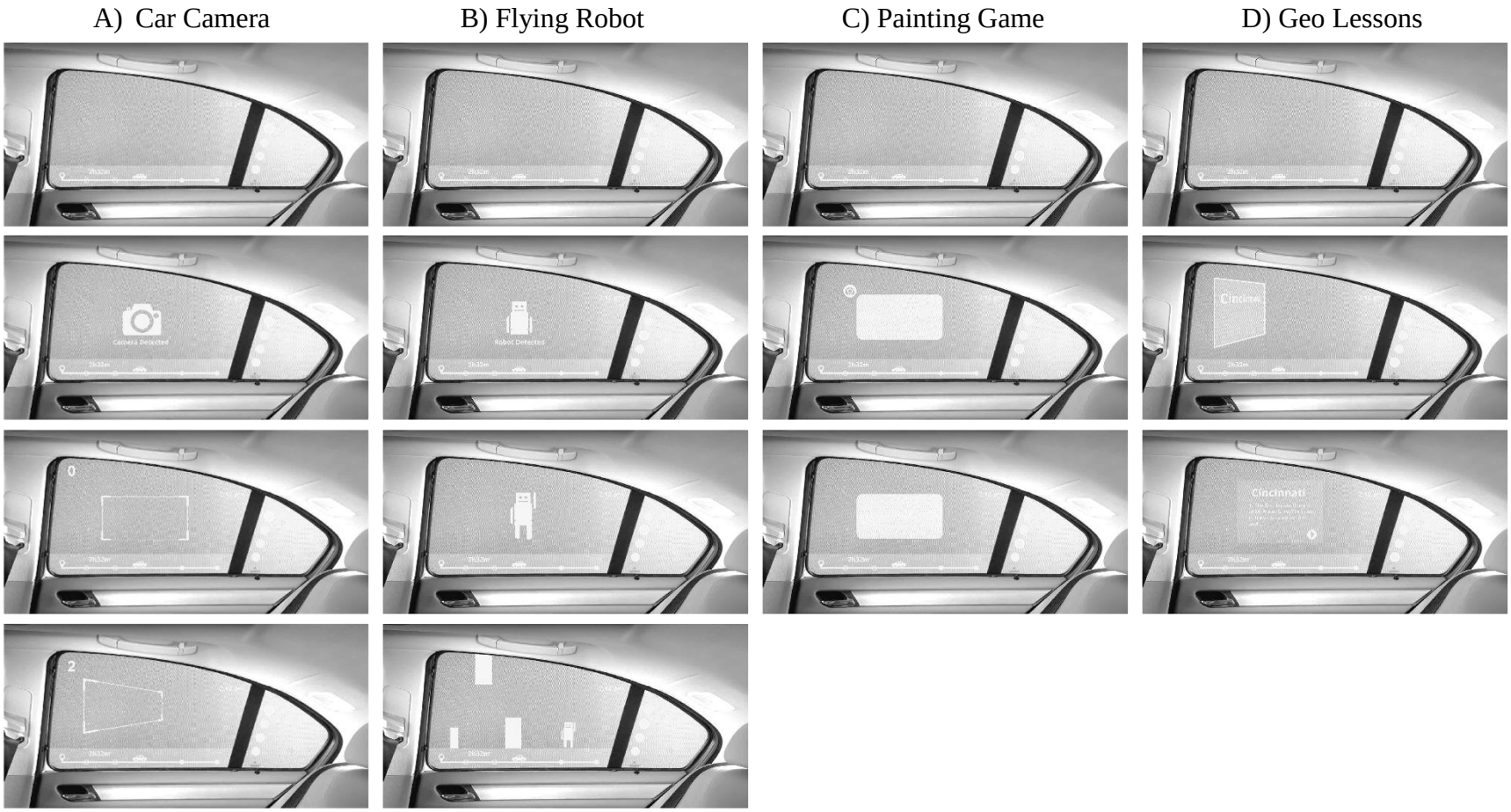


Figure 29: AR interactive window (wireframe)

5.6 Visual Design

After having the clear concept of entire design and the nearly finalized wire frames, I started adding the visual elements to the interfaces. As shown in Figure 30, the main color of the interfaces is yellow, which means happiness and optimism in color theory. It is truly a joyous and radiant color, exuding warmth, inspiration, creativity, and vitality. The entire system intends to build a warm and joyous in-car environment for families and also desires to bring creative activities to children. Therefore after consideration I decided to use yellow as the main color for the interfaces with other prime colors as supplements. The selected font is Noto Sans. Noto Sans is a sans serif font, which is easy to read on the interfaces.

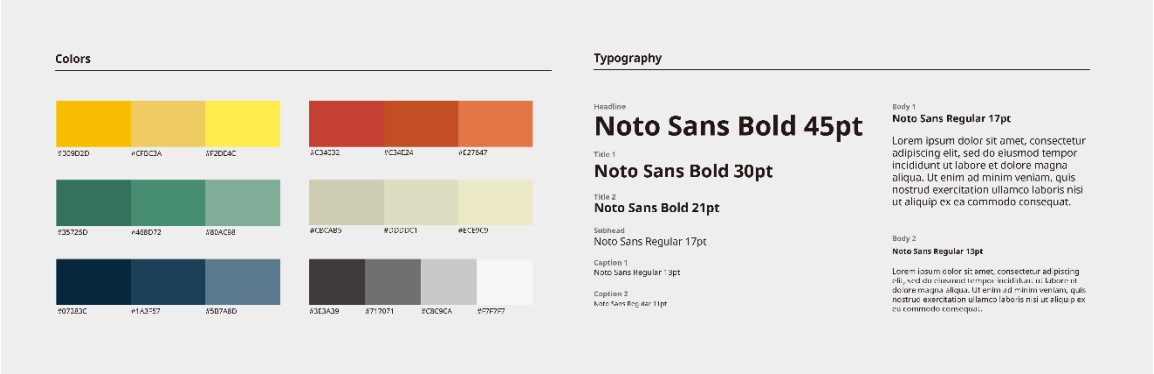


Figure 30: Style guide

Moreover, the shapes of tailored icons are inspired by the interactive block. Most of these examples are cubic (as Figure 31).

Figure 31: Cubic icons

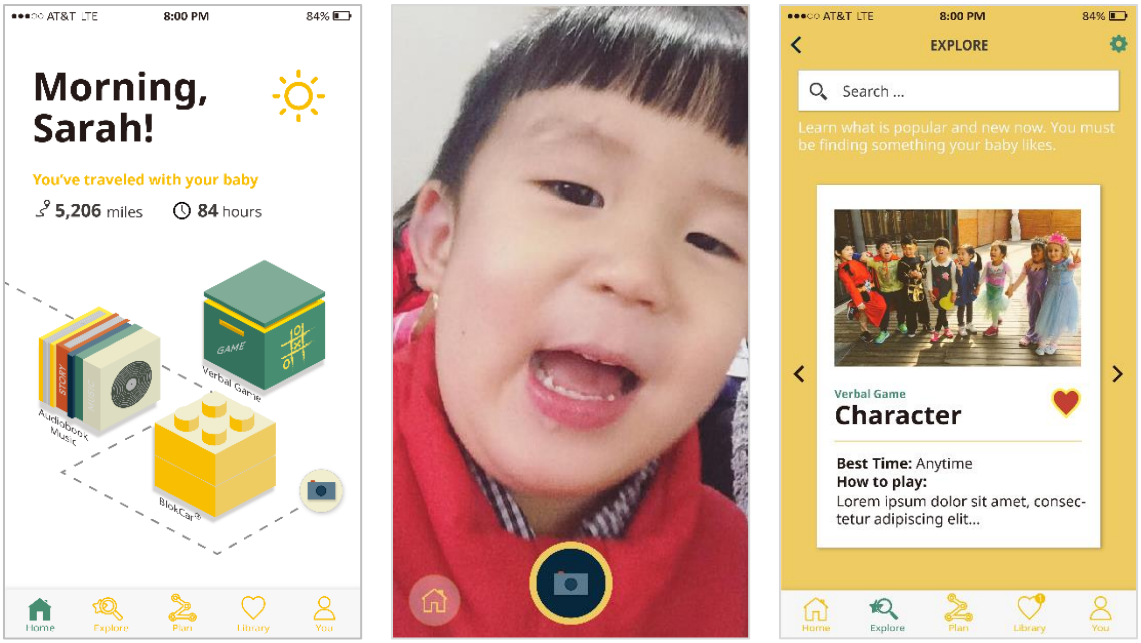


Figure 32: Home page, live cam and explore

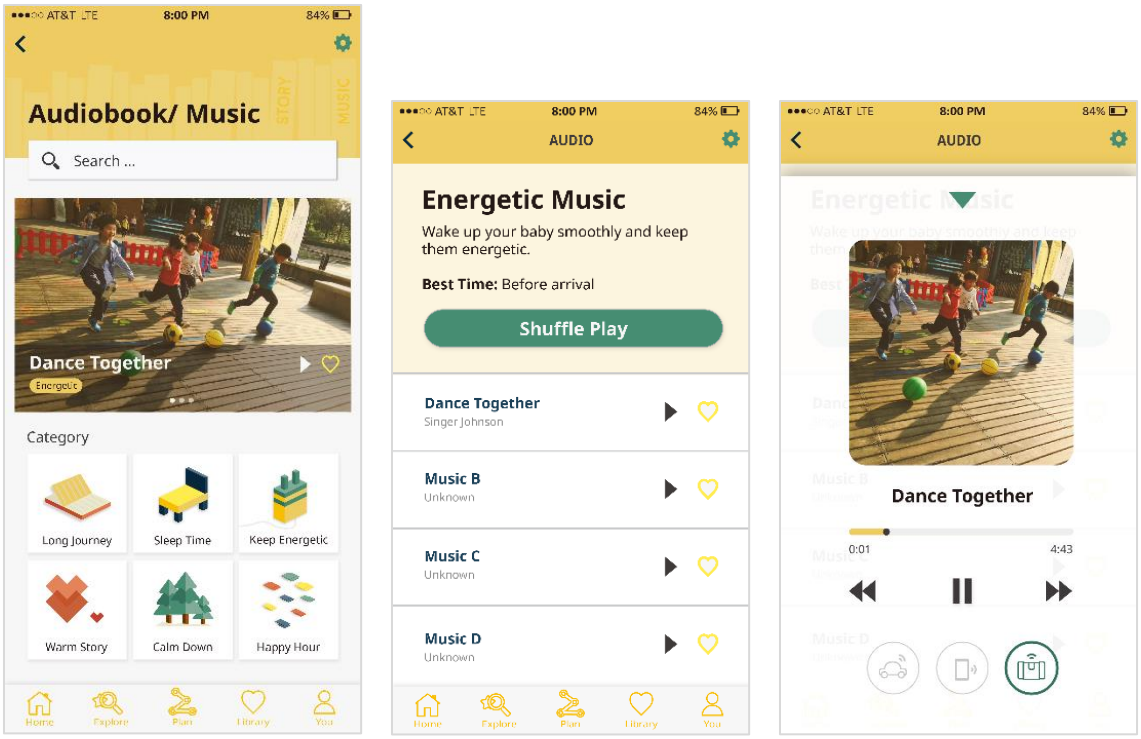


Figure 33: Audiobook/ Music

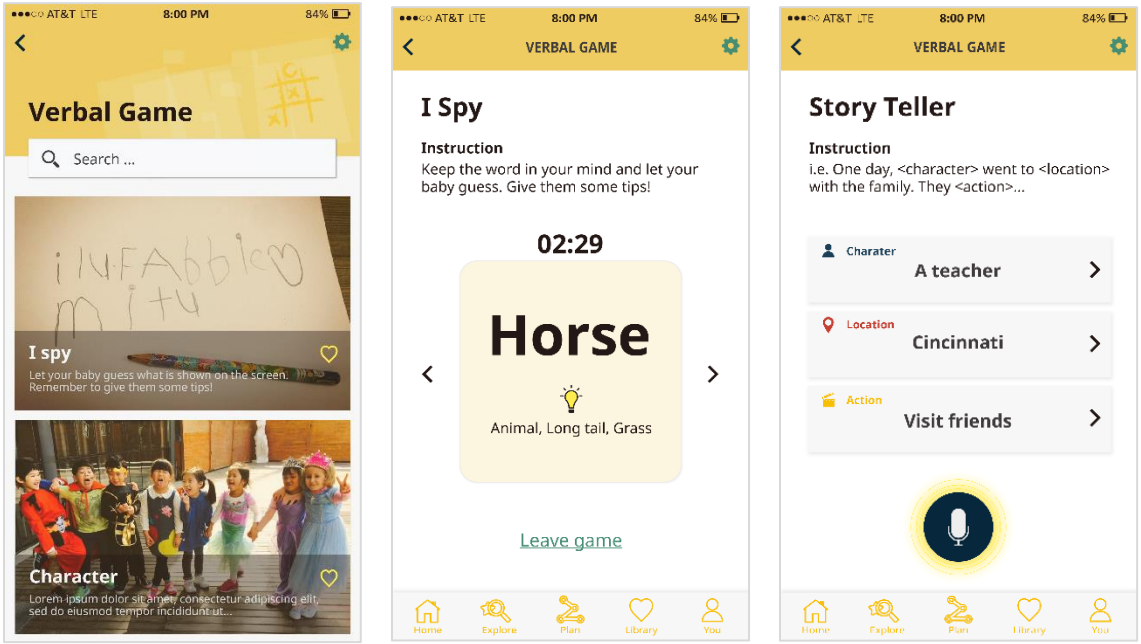


Figure 34: Verbal games

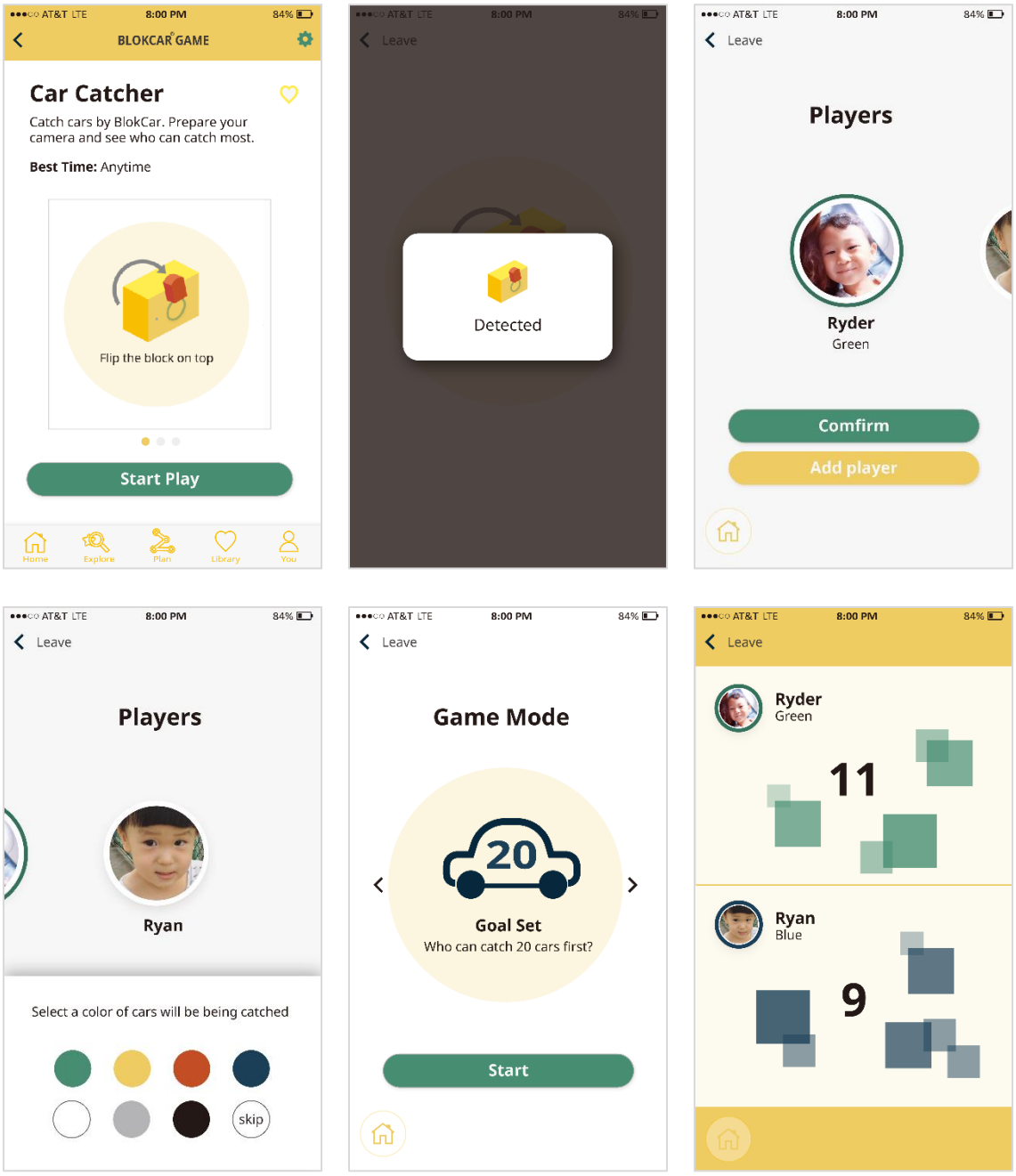


Figure 35: BlokCar game- Car Catcher

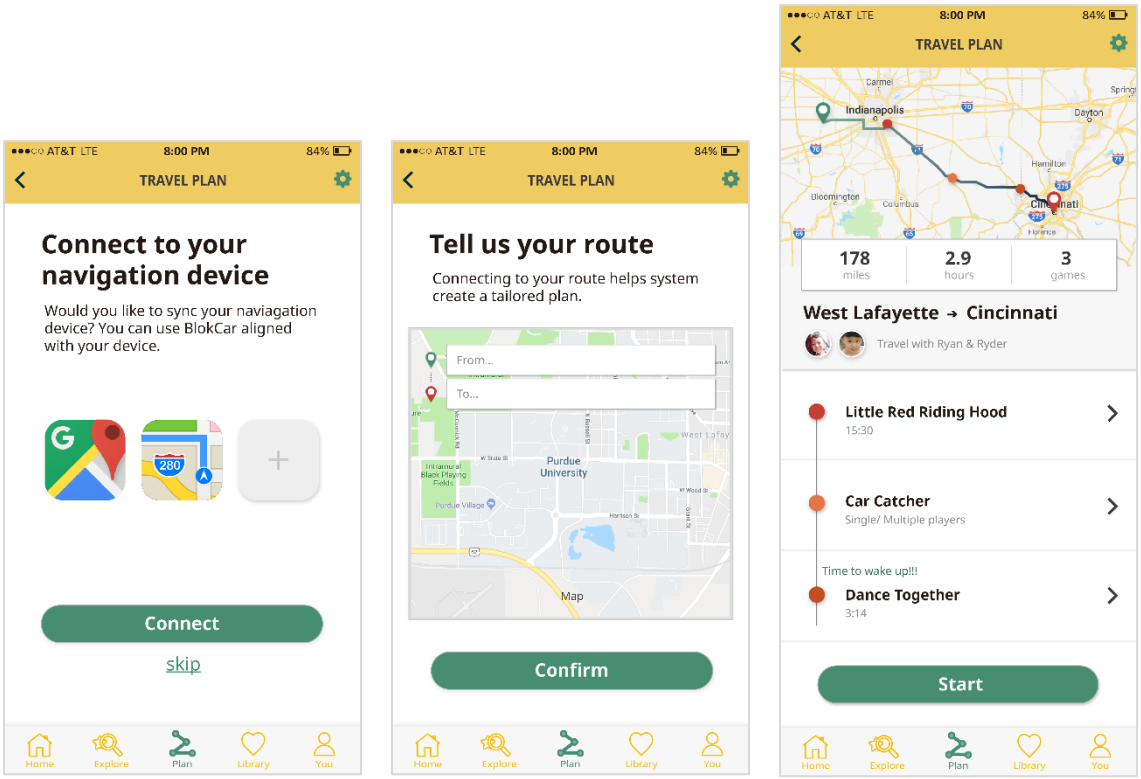


Figure 36: Travel plan

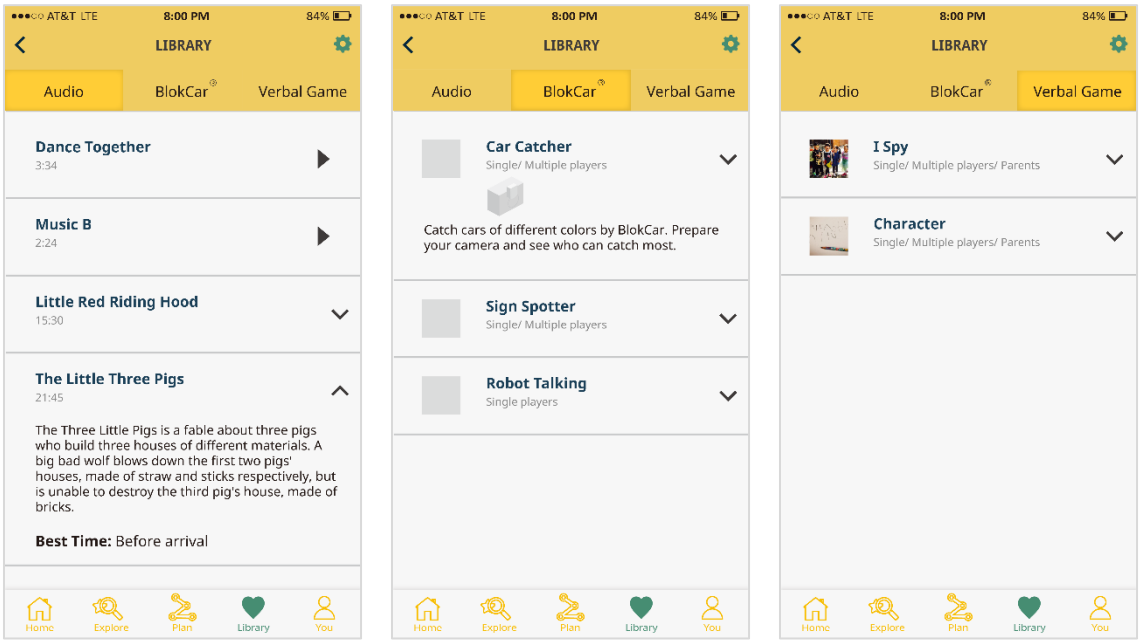


Figure 37: Library

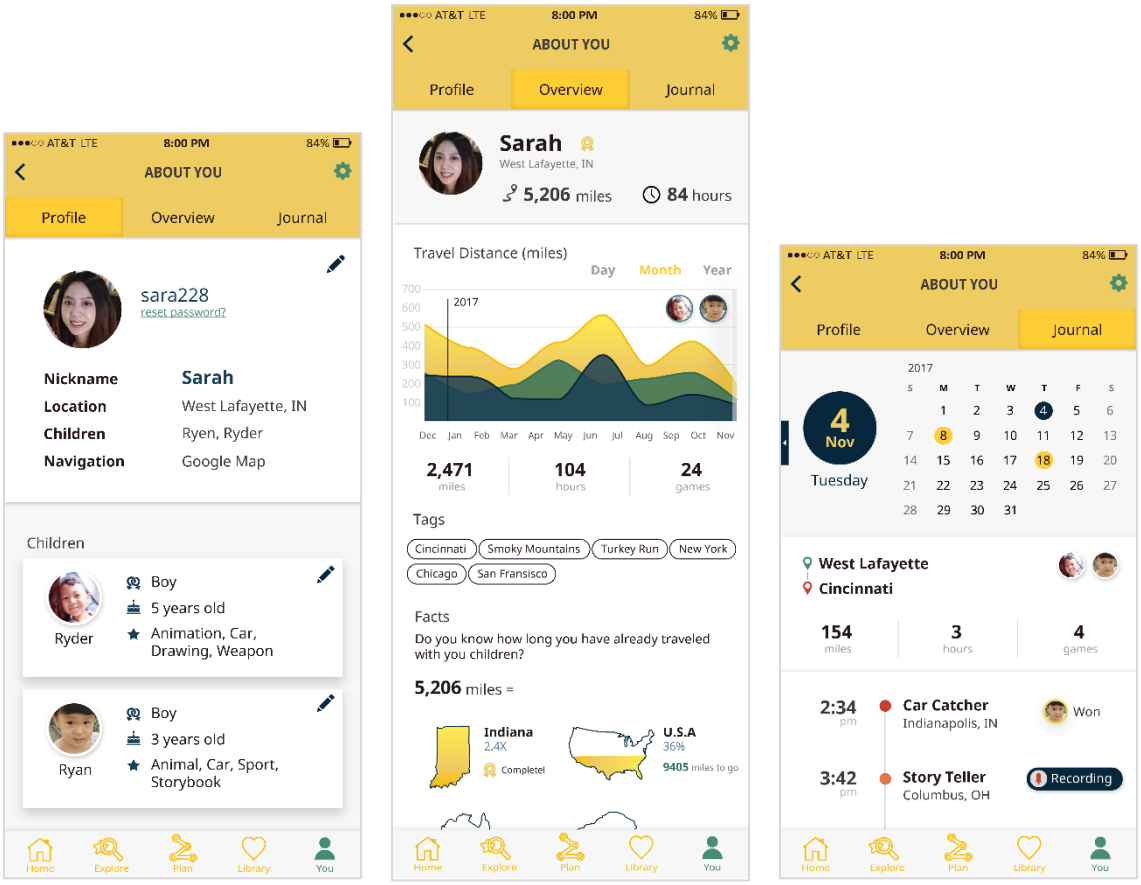


Figure 38: Travel history & memorable data

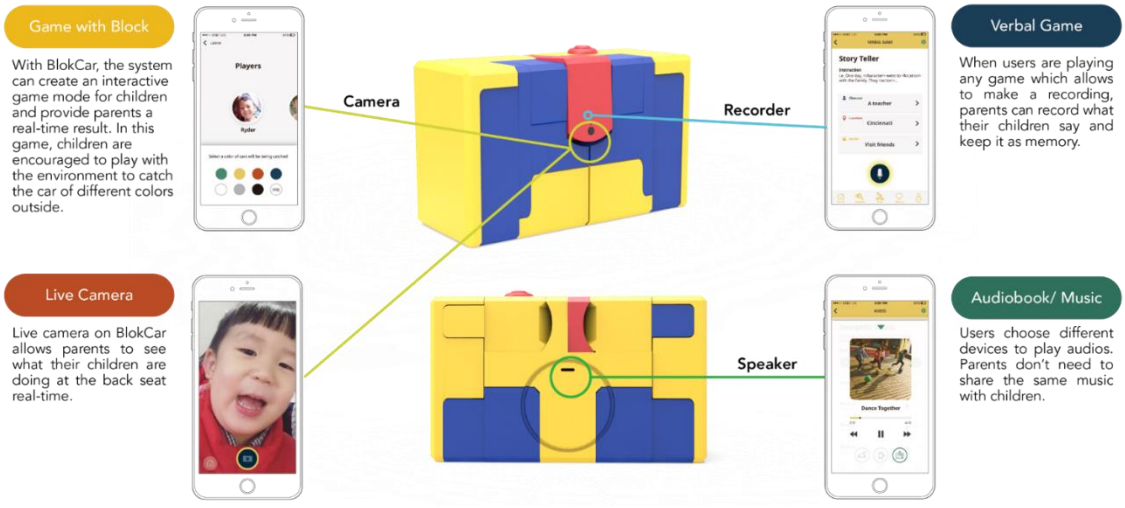


Figure 39: Interaction modes between BlokCar and mobile application

Figure 40: Interfaces of AR interactive window

5.7 Summary

In this chapter, I reviewed the design process from ideation to detail design. Here I have mainly highlighted the establishment and refinement of the design framework and the development of design details.

CHAPTER 6 EVALUATION

Evaluation can be classified into two categories (Scriven, 1967). One is formative evaluation, which indicates the evaluations conducted during the design process to help forming the final design. And the other one is summative evaluation, which is normally used to evaluate the final outcomes. Although the iterative design process based on the formative evaluations and continuous improvements is introduced in the previous chapter, here I will mainly discuss the summative evaluation methods I used on this project to reach findings from the evaluations, and finally, the directions for the future work.

6.1 Heuristic Evaluation

Developed by Nielsen and Molich (1990), heuristic evaluation is an efficient and economical evaluation method broadly used in the interaction design domain. The participants are usually the experts for certain domains, but the evaluation is also valid for use to recruit a novice user to do the evaluation. The participants are provided with the usability heuristics before evaluation and then they identify the problems according to the heuristics. The researcher will request them to rate the severity of each problem and analyze the results to get the insights. For this cross-media interaction project, I consult the heuristics proposed by Clarkson and Arkin (2007), to evaluate the human-robot interaction system and also refer to the probably most-used usability heuristics for user interface, developed by Nielsen (1994), as the supplement. The goal of this evaluation is to examine the interfaces and the interactive block and test the interaction between the

mobile application and the physical block, BlokCar. The AR interactive window is not evaluated for this time because it is a conceptual design challenging the existing technology, and it probably needs more future research to support and develop. Currently, the evaluation on the AR interactive window is probably ineffective. Therefore, with focus on interfaces of the mobile application, the interaction between each element, and the usability of the interactive block, the heuristics I selected for this project are shown below.

A. *Sufficient information design* (Clarkson & Arkin, 2007; Nielsen, 1994; Scholtz, 2002)
B. *Visibility of system status* (Clarkson & Arkin, 2007; Nielsen, 1994)
C. *Appropriate information presentation* (Clarkson & Arkin, 2007; Scholtz, 2002)
D. *Use natural cues* (Clarkson & Arkin, 2007; Nielsen, 1994; Scholtz, 2002)
E. *Synthesis of system and interface* (Clarkson & Arkin, 2007)
F. *Help users recognize, diagnose, and recover from errors* (Clarkson & Arkin, 2007; Nielsen, 1994; Scholtz, 2002)
G. *User control and freedom* (Nielsen, 1994)
H. *Flexibility and efficiency of use* (Nielsen, 1994)
I. *Aesthetic and minimalist design* (Clarkson & Arkin, 2007; Nielsen, 1994)
J. *Error prevention* (Nielsen, 1994)

For the evaluation, I recruited three graduate students from Purdue. Two are majored in interaction design, and the other is a major in mechanical engineering with the track of robotic engineering. The participants with interaction design background are

experts of user interface design and interaction design. And the student from mechanical engineering can provide more professional feedback on the design of interactive block, BlokCar. The result will be discussed in the following section.

Figure 41: Documentation and prototypes for the evaluation

Heuristics		
A	Sufficient information design	The interface should be designed to convey "just enough" information: enough so that the human can determine if intervention is needed, and not so much that it causes overload.
B	Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time. The system should convey its world model to the user so that the user has a full understanding the system's situational awareness.
C	Appropriate information presentation	The interface should present sensor information that is easily understood and in a useful form. The system should use the principle of recognition over recall, externalizing memory and improving users' situational awareness via attention management.
D	Use natural cues	The language of the interaction between the user and the system should be in terms of words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
E	Synthesis of system and interface	The interface and system should blend together so the interface is an extension of the user, the system and by proxy, the world. The interface should facilitate efficient communication between system and user, switching modes automatically when necessary.
F	Help users recognize, diagnose, and recover from errors	System malfunctions should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. The system should present enough information about the task environment so that the user can determine if some aspect of the world has contributed to the problem.
G	User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
H	Flexibility and efficiency of use	Accelerators — unseen by the novice user — may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
I	Aesthetic and minimalist design	The physical embodiment of the system should be pleasing in its intended setting. The system should not contain information that is irrelevant or rarely needed.
J	Error prevention	Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

			Disagree				Agree	
Questions		Heuristic	1	2	3	4	5	Comments (Pros & Cons)

Figure 42: Heuristics for the reference of participants on the form

6.2 Feedback Collected from Exhibition

The project was presented in an exhibition held for two weeks at the end of March 2018 (see Figure 43). In the gallery, the audience can have a closer look at BlokCar, the interactive block, and better understand the project from the posters, videos, and presentation. Without the fully functional BlokCar, to allow the audience acknowledge the interaction among the three components is a challenge. In this situation, the introduction video (see Figure 44) is the most effective way to demonstrate the details of interaction and give the audience a clear image of the whole system. The exhibition, equipped with posters, videos, prototypes, and physical models, was a good opportunity to collect audience feedbacks and summative evaluate the project. I observed behavior of the audience, which showed interest in the project and saw how they interacted with BlokCar. Some of the audience are the potential users, such as children. This was a chance to evaluate the usability of BlokCar to see if the interactive block attracted them and allowed them to easily understand how to play with it. After their own explorations, I walked toward them to ask for feedbacks. The feedbacks are organized and will be discussed in the next section.

6.3 Data Analysis & Findings

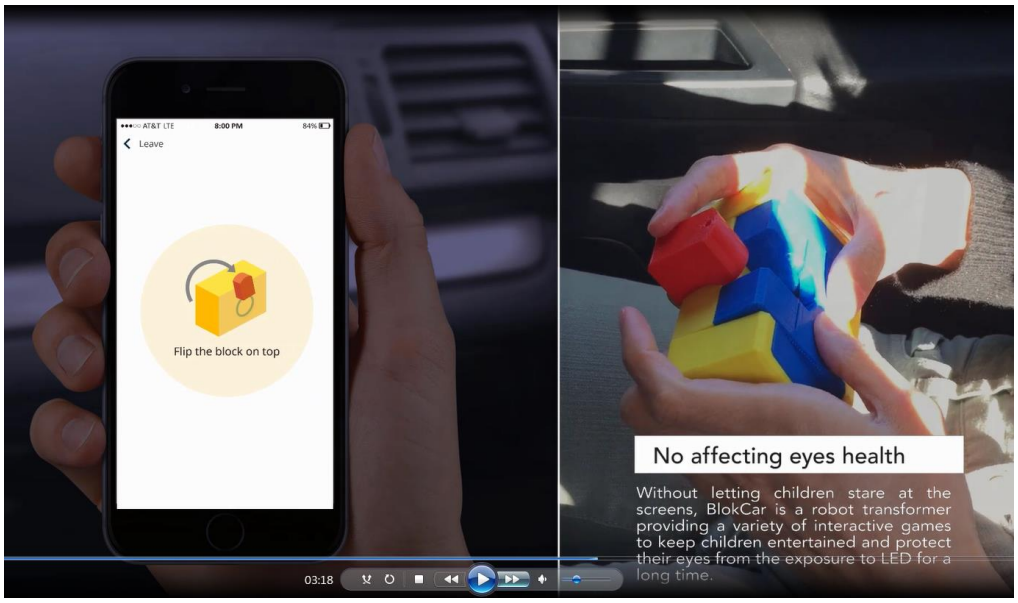
After collecting the result from the three participants, I organized the data and made the chart (see Table 4) to enable an easy examination. Participant one is a student with a mechanical engineering background, and participants two and three are from interaction design majors. From the result, I learned that participant one was more focused on the functionality of the system; the other two participants paid more attention to the interaction concept and interfaces. Here are the cons and pros. The unfavorable point is that because this project is more conceptual, it is probably not so suitable for the usability evaluations. It sometimes causes much confusion because it is not functional and has no ability to demonstrate the real interaction. However, this is also the favorable point. Because of the challenge, I can realize that the miscommunication is between the potential users and the concept of the system. It provides me a chance to rethink how to better present the idea with limited resources. This is a big finding for the evaluation setting and the idea presentation. As for findings of the system's usability evaluation, the top problems are listed below.

1. *Users have no idea about how to use BlokCar- the interactive block for the first time***.** (3 times mentioned)
2. *There is no clue to show children how to interact with the mobile application by using BlokCar.* (2 times mentioned + feedback from exhibition)
3. *Users have no idea how to activate an AR interactive window.*
   (2 times mentioned)

4. *BlokCar appears easy to be damaged by children.* (1 time mentioned + feedback from exhibition)
5. *The wings of BlokCar are hard to be unfolded.* (1 time mentioned + feedback from exhibition)
6. *The color of BlokCar is inconsistent with the color scheme of the interfaces.* (1 time mentioned)
7. *The mobile application is slightly complex.* (1 times mentioned)
8. *Users need to go back to the main page to choose other types of entertainment.* (1 time mentioned)
9. *The route plan function is confusing if it needs to be used concurrently with the navigation devices.* (1 time mentioned)
10. *Users may not easily understand how to use the entire system without learning.* (1 time mentioned)
11. *The selection of colors on BlokCar should be considered more carefully.* (1 time mentioned)

Figure 43: Presentation on the exhibition

A)



B)

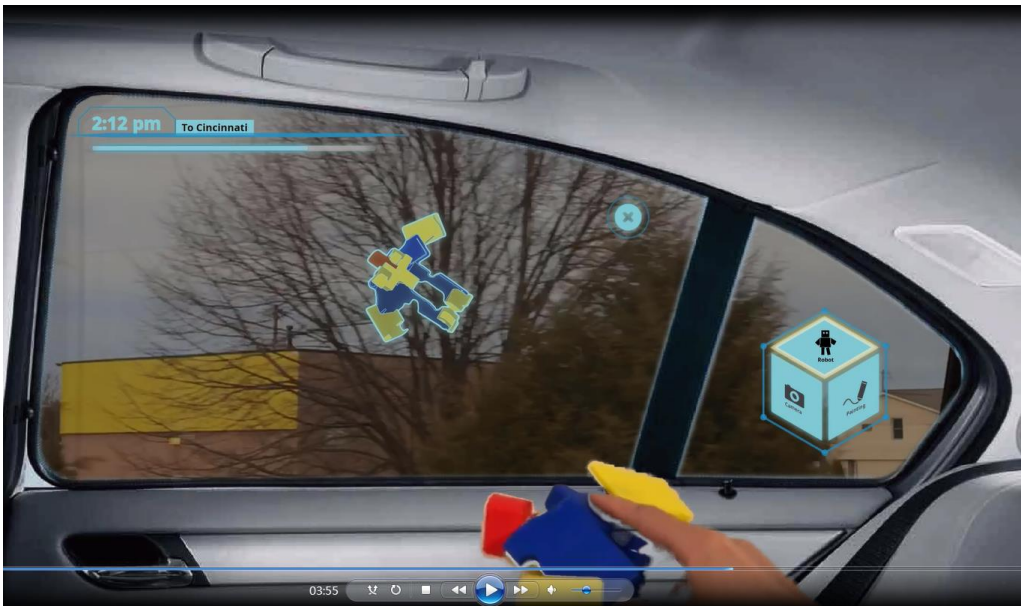


Figure 44: Screenshots of the intro video

6.4 Directions for Future Work

Based on the analyzed results and identified problems, I found that most of the participants pointed out the affordance issue of BlokCar, the interactive block. They have

no idea of how to use it and how it can interact with the mobile application and the AR interactive window. For the future work of this project, the affordance issue should be the first priority. BlokCar involves the technology of tangible interaction. It is usually challenging for a tangible interactive product to clearly provide the feedback in an invisible interaction. But this will be a big leap for these types of products to create a better user experience. It will be a good research topic to continue. Besides, the design of BlokCar should also be improved. One direction is to provide different combinations of colors for different groups of users, or even to add the face to the block to create the personality of BlokCar. But it also needs to carefully consider the consistency between the mobile application and BlokCar if they are in the different colors. Regarding the mechanism of BlokCar, I personally understand there is still big room for improvement. But I may need to seek help from the experts on this domain. Once the technology is fully prepared, I believe the concept will also be completely realized. Lastly is the learnability and efficiency of the mobile application. The application aims to provide a comprehensive set of functions, but it also reduces its intuition to use. Therefore repetitive testing on the user flows is necessary to understand the browsing behavior of most users and further make improvements based on the findings. To summarize, here are four directions for the future work.

- *Affordance of BlokCar- the interactive block, a tangible interactive toy*
- *Visual design of BlokCar for different groups of users*
- *Mechanical design of BlokCar*
- *Learnability and efficiency of the mobile application*

Table 4: Evaluation result

Questions	Heuristic	#1	#2	#3	Total rating	Mean rating
1. You have a clear idea of what the system is from the information it provides	A	1	1	1	3	1.0
2. The system provides just enough information without overloading you.	A, I	3	0	1	4	1.3
3. You seldom get lost in the system. The system overall gives a good feedback to informing you the step you are.	B	2	0	1	3	1.0
4. You are clear about the meaning of the icons or buttons and you can successfully browse the pages by using them.	C	1	0	1	2	0.7
5. You overall understand all of the information shown on the application.	C	1	0	1	2	0.7
6. You can learn how to interact with the block through the information or feedback the application provides.	B	1	1	2	4	1.3
7. Overall, the system uses the simplest language and universal visual representations.	D	1	0	1	2	0.7
8. The interface and interaction of this system keep consistent.	E	1	1	1	3	1.0
9. The system lets you recover from the errors (i.e. have a wrong setting) without anyone's help and avoid the error next time.	F	2	0	1	3	1.0
10. The system (Application and Block) provides the freedom of use and flexibility.	G, H	2	1	0	3	1.0
11. The application speeds up the interaction for the expert user, such as shortcut and favorite items.	H	0	0	0	0	0.0
12. You can quickly go back to the previous page or main page.	G	0	0	0	0	0.0
13. The interfaces overall are clean and aesthetical.	I	1	1	1	3	1.0
14. You are satisfied with the system.	I	1	0	1	2	0.7
15. The system has the indicators or mechanisms for you to avoid errors.	J	2	1	2	5	1.7
16. You can easily understand and remember how to use the system.	A, B, C, F	1	1	1	3	1.0
17. The system provides useful information or takes into effect.	A, C	1	0	1	2	0.7
18. The system can save the time for parents and relieve the boredom for children.	H	2	0	0	2	0.7

Table 5: Severity rating

0	Not a problem. Improvement opportunity.
1	Cosmetic Problem. It may improve user experience.
2	Usability Problem. Impact on manual or equipment use.
3	Major Usability Problem. It results on inappropriate operation or miss programming.
4	Usability Catastrophic. It results on equipment damage, patient or operator harm.

CHAPTER 7 CONCLUSION

This project attempted to open a new area for the research domain of Human-Car Interaction. Shifting the focus from drivers to passengers, it considers the future of in-car interaction as the era of self-driving cars develops. The entire system includes three components: 1. Mobile Application, 2. Interactive Block-BlokCar, and 3. AR Interactive Window. The mobile application collects the resources and clearly categorizes the resources based on user needs. It allows users to explore what they like and store their favorites in the library. The instructions are also provided to better guide users to participate in the games. Moreover, the mobile application is location-based; thus it can present the suggestions of games or audios based on children's preferences, travel plans, and road conditions. For child passengers, the interactive block, Blokcar, allows them to play a variety of interactive games with the traditional block functions. In a limited car space, its multifunction creates more possibilities of a toy and develops the creativity of children. It also connects with the mobile application and aims to provide the same level of entertainment as a digital device does without compromising their eye health. Furthermore, the AR interactive window enhances the experience of in-car entertainment. It makes children more interesting in the surroundings and builds a new value to road trips. Their playground is no more limited only to the car space. They can interact with the environment, passersby, and all of the element they can see through the window. When arriving at a destination, the mobile application will record the travel history automatically and generate the memorable data. During the journey, parents can also keep the memory in different media, such as photos and voice recordings. The system

cares about every section of the journey, from preparation and planning before departure, interaction and entertainment during the travel, and finally memory storage after arrival. Based on literature review, many parents value the quality time spent with their children (Price & Matthews, 2013; Wilfinger et al., 2011) but they also have a hard time traveling with them (Daily Mail, 2011). Traveling with children also causes distractions and may compromise safety (Koppel et al., 2011; Wilfinger et al., 2011). According to user research, many interviewees reported that preparation and planning are more complex if traveling with children. They usually must prepare the entertainment devices, toys, storybooks, music, and so on in advance. In a limited space, children easily get bored and unwilling to behave themselves. They found that digital devices are the most effective tool for entertaining children, but they also worry about the eyes health issue. After reviewing the existing products, I understood the problems having not been well solved. The experience of family car travel still needs improvement.

From the exploration of new research domain to the finding of better solutions, this project not only solves the problems identified from the researches I have done, but it also builds a new experience of an in-car entertainment system and also of family trips.

REFERENCES

3DCentral. (n.d.). Robot transformer 3D printed toy on Etsy. Retrieved April 24, 2018, from https://www.etsy.com/listing/156327980/robot-transformer-3d-printed-toy?utm_source=OpenGraph&utm_medium=PageTools&utm_campaign=Share

Areaware. (n.d.). Cubebot. Retrieved April 24, 2018, from https://www.areaware.com/collections/cubebot

Bishop, R. (2005). *Intelligent vehicle technology and trends*. Norwood, MA: Artech House

Brookhuis, K. A., de Vries, G., & De Waard, D. (1991). The effects of mobile telephoning on driving performance. *Accident Analysis & Prevention*, *23*(4), 309–316.

Brown, I. D., Tickner, A. H., & Simmonds, D. C. (1969). Interference between concurrent tasks of driving and telephoning. *Journal of Applied Psychology*, *53*(5), 419.

Broy, N., Goebl, S., Hauder, M., Kothmayr, T., Kugler, M., Reinhart, F., … André, E. (2011). A cooperative in-car game for heterogeneous players. In *Proceedings of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 167–176). ACM.

Brunnberg, L., Juhlin, O., & Gustafsson, A. (2009). Games for passengers: Accounting for motion in location-based applications. In *Proceedings of the 4th International Conference on Foundations of Digital Games* (pp. 26–33). ACM.

Buchenau, M., & Suri, J. F. (2000). Experience prototyping. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques* (pp. 424–433). ACM.

Clarkson, E., & Arkin, R. C. (2007). Applying heuristic evaluation to Human-Robot Interaction systems. In *Flairs Conference* (pp. 44–49).

Cooper, A., Reimann, R., & Cronin, D. (2007). *About face 3: The essentials of interaction design*. John Wiley & Sons.

Csikszentmihalyi, M. (1978). Attention and the holistic approach to behavior. In *The Stream of Consciousness* (pp. 335–358). Springer.

Daily Mail. (2011). Bored children's first cry comes just 30 minutes into car journeys. Retrieved April 22, 2018, from http://www.dailymail.co.uk/news/article-2015270/Bored-childrens-comes-just-30-minutes-car-journeys.html

Davies, D. R., Shackleton, V. J., & Parasuraman, R. (1983). Monotony and boredom. *Stress and Fatigue in Human Performance*, 1–32.

De Chenne, T. K., & Moody, A. J. (1988). Boredom: Theory and therapy. *The Psychotherapy Patient*, *3*(3–4), 17–29.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining gamification. In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9–15). ACM.

Diewald, S., Möller, A., Roalter, L., & Kranz, M. (2011). Mobile device integration and interaction in the automotive domain. In *AutoNUI: Automotive Natural User Interfaces Workshop at the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2011)*.

Dix, A. (2009). Human-computer interaction. In *Encyclopedia of Database Systems* (pp. 1327–1331). Springer.

Fisherl, C. D. (1993). Boredom at work: A neglected concept. *Human Relations*, *46*(3), 395–417.

General Motors, & Bezalel Academy of Art and Design. (2012). GM explores windows of opportunity. Retrieved April 23, 2018, from http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2012/Jan/0118_research.html

Green, P. (1999). The 15-second rule for driver information systems. In *Proceedings of the ITS America Ninth Annual Meeting*. Intelligent Transportation Society of America Washington, DC.

Häkkilä, J., Colley, A., & Rantakari, J. (2014). Exploring mixed reality window concept for car passengers. In *Adjunct Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 1–4). ACM.

Hanington, B., & Martin, B. (2012). *Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions*. Rockport Publishers.

Harvey, C., Stanton, N. A., Pickering, C. A., McDonald, M., & Zheng, P. (2011). In-vehicle information systems to meet the needs of drivers. *Intl. Journal of Human–Computer Interaction, 27*(6), 505–522.

Hedlund, J., Simpson, H. M., & Mayhew, D. R. (2006). International conference on distracted driving: Summary of proceedings and recommendations: October 2-5, 2005. CAA.

Hewett, T. T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M., … Verplank, W. (1992). *ACM SIGCHI curricula for human-computer interaction*. ACM.

Hock, P., Benedikter, S., Gugenheimer, J., & Rukzio, E. (2017). CarVR: Enabling in-car virtual reality entertainment. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 4034–4044). ACM.

Hoffman, G., Gal-Oz, A., David, S., & Zuckerman, O. (2013). In-car game design for children: Child vs. parent perspective. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 112–119). ACM.

Honda. (2017). Honda teams with DreamWorks animation to create virtual reality "Honda Dream Drive" Experience. Retrieved April 23, 2018, from http://hondanews.com/releases/honda-teams-with-dreamworks-animation-to-create-virtual-reality-honda-dream-drive-experience

Inbar, O., & Tractinsky, N. (2011). Make a trip an experience: Sharing in-car information with passengers. In *CHI'11 Extended Abstracts on Human Factors in Computing Systems* (pp. 1243–1248). ACM.

Kern, D., & Schmidt, A. (2009). Design space for driver-based automotive user interfaces. In *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 3–10). ACM.

Kodama, R., Koge, M., Taguchi, S., & Kajimoto, H. (2017). COMS-VR: Mobile virtual reality entertainment system using electric car and head-mounted display. In *3D User Interfaces (3DUI), 2017 IEEE Symposium on* (pp. 130–133). IEEE.

Koppel, S., Charlton, J., Kopinathan, C., & Taranto, D. (2011). Are child occupants a significant source of driving distraction? *Accident Analysis & Prevention*, *43*(3), 1236–1244.

Laubheimer, P. (2016). Wireflows: A UX deliverable for workflows and apps. Retrieved April 23, 2018, from https://www.nngroup.com/articles/wireflows/

Leary, M. R., Rogers, P. A., Canfield, R. W., & Coe, C. (1986). Boredom in interpersonal encounters: Antecedents and social implications. *Journal of Personality and Social Psychology*, *51*(5), 968.

Mikulas, W. L., & Vodanovich, S. J. (1993). The essence of boredom. *The Psychological Record*, *43*(1), 3.

Myers, B. A. (1998). A brief history of human-computer interaction technology. *Interactions*, *5*(2), 44–54.

NHTSA. (2016, September 8). Distracted driving. Retrieved April 22, 2018, from https://www.nhtsa.gov/risky-driving/distracted-driving

Nielsen, J. (1994). Usability inspection methods. In *Conference companion on Human factors in computing systems* (pp. 413–414). ACM.

Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 249–256). ACM.

Pfleging, B., & Schmidt, A. (2015). Driving-related activities in the car: Defining driver activities for manual and automated driving. In *Workshop on experiencing autonomous vehicles: Crossing the boundaries between a drive and a ride at CHI* (Vol. 15).

Pickering, C. A., Burnham, K. J., & Richardson, M. J. (2007). A review of automotive human machine interface technologies and techniques to reduce driver distraction. In *2nd Institution of Engineering and Technology international conference on system safety* (pp. 223–228). IET.

Price, L., & Matthews, B. (2013). Travel time as quality time: Parental attitudes to long distance travel with young children. *Journal of Transport Geography*, *32*, 49–55.

Regan, M. A., Lee, J. D., & Young, K. (2008). *Driver distraction: Theory, effects, and mitigation*. CRC Press.

Schleicher, D., Jones, P., & Kachur, O. (2010). Bodystorming as embodied designing. *Interactions*, *17*(6), 47–51.

Schmidt, A., Dey, A. K., Kun, A. L., & Spiessl, W. (2010). Automotive user interfaces: human computer interaction in the car. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems* (pp. 3177–3180). ACM.

Scholtz, J. (2002). *Evaluation methods for human-system performance of intelligent systems*. Gaithersburg MD: National Inst of Standards and Technology Manufacturing Engineering Lab.

Schwarz, S., Proschofski, S., & Meschtscherjakov, A. (2016). Playing videos for infants on the rear Seat: An evaluation of different approaches. In *Adjunct Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 161–166). ACM.

Scriven, M. S. (1967). The methodology of evaluation (perspectives of curriculum evaluation, and AERA monograph series on curriculum evaluation, no. 1). *Chicago: Rand NcNally*.

Smith, P. C. (1955). The prediction of individual differences in susceptibility to industrial monotony. *Journal of Applied Psychology*, *39*(5), 322.

Stevens, A., Quimby, A., Board, A., Kersloot, T., & Burns, P. (2002). Design guidelines for safety of in-vehicle information systems. *TRL Limited*.

Telematics News. (2011, June 22). EU: Toyota adds augmented reality content to car's windows. Retrieved April 23, 2018, from http://telematicsnews.info/2011/06/22/eu-toyota-adds-augmented-reality-content-to-cars-windows_jn2223/

Wilfinger, D., Meschtscherjakov, A., Murer, M., Osswald, S., & Tscheligi, M. (2011). Are we there yet? A probing study to inform design for the rear seat of family cars. In *IFIP Conference on Human-Computer Interaction* (pp. 657–674). Springer.

Williams, A. (2009). User-centered design, activity-centered design, and goal-directed design: A review of three methods for designing web applications. In *Proceedings of the 27th ACM international conference on Design of communication* (pp. 1–8). ACM