DESIGN AND DEVELOPMENT OF AN AUGMENTED REALITY PLATFORM TO
CONNECT GRANDPARENTS AND GRANDCHILDREN ACROSS DISTANCES

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Fine Arts in Industrial Design
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2019

Urbana, Illinois

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ABSTRACT

Globalization and urban migration have led to a larger number of families that live away from each other. This raises issues particularly for the elderly population as they deal with both loneliness and depression, coupled with a decline in mobility and physical well-being. On the other hand, childhood depression is also on the rise, with youngsters today spending almost double the time on screens as they used to in 1965. Loneliness has also been linked to an increase in mortality rates and a decline in physical health and mental health. This project explores the relationship between grandparents and their grandchildren, with a focus on people that are separated by distance.

This paper details the design and development of an augmented reality platform that was designed to help create a platform for play, where stories, experiences, and skills can be shared across distances, between these two user groups. The final design was developed based on insights from literature review, analysis of current demographics and device usage patterns, an analysis of current problems and existing solutions along with the development of fictional user personas, journey maps, empathy maps, and prototyping. The design outcome is in the physical + digital space, with the creation of a mixed reality platform to establish connections between the two generations. The components of the system include projection mapping, a physical product, a screen-based User Experience solution, and the development of a character.

To my grandmother, Chandra Doshi, who sparked the initial idea behind

this work.

ACKNOWLEDGEMENTS

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CHAPTER 1: BACKGROUND

1.1 Demographics of Older adults

Definition of elderly

The American Association of Retired Persons' (AARP) 2004 study found that previous studies (undertaken during 2000 - 2004) of the elderly and their use of the ICT and the Web used a variety of definitions, from 50+ years through to 65+ years [Redish & Chisnell 2004]. Bailey [Bailey 2002] [Bailey 2004] reviewed a number of studies and journals and proposed the following classification:

Young: 18-39 years

Middle-aged: 40-59 years

Older: 60-74 years

Old-old: 75+ years

The AARP itself considers 'older adults' to be those over 50 years, while many western countries (including the USA) consider the retirement age to be 65 years. (Web Accessibility for Older Users: A Literature Review) For the purpose of this thesis Older adults are defined as adults over the age of 65 years.

The population of older adults in the United States has been growing both in absolute numbers and as a proportion of the overall population. According to the 2012 US

Census reports the population aged 65 and over is projected to almost double from 43.1 million in 2012 to 83.7 million in 2050. This is credited largely to the baby boomers as they began turning 65 in 2011. (Ortman et al.) As of 2016, adults aged 65 or older comprise of 15.24% of the population in the United States with a projected growth to 23.51% by 2060. (Bureau, 2017 National Population Projections Tables)

By 2020, there will be about three-and-a-half working-age adults for every retirement-age person. By 2060, that ratio will fall to just two-and-a-half working-age adults for every retirement-age person. (Bureau, "Older People Projected to Outnumber Children") With the growing usage of technology for communication, it is important to take the needs of older adults into account.

1.2 Demographics of children

As of 2016, the under 18 year age group makes up about 22.79% of the population of the United States. In absolute numbers this age group comprises about 73,642,000 individuals. Census data further breaks the under 18 population segment into under 5 years (6.17%), 5-13 years (11.44%) and 14 - 17 years (5.19%). (Bureau, 2017 National Population Projections Tables)

1.3 Loneliness amongst older adults

From 1980 to 2015, the percentage of divorced men grew from 4% to 11% and from 3%

to 13% for women in the same period. The share of divorced women ages 65 and older

increased from 3 percent in 1980 to 13 percent in 2015, and for men from 4 percent to

11 percent during the same period. More than 25% of women between the ages of 64 to

75 lived alone in 2014. This percentage jumps to 42% amongst women in 75 to 84 age

group. (Mather) This becomes an important factor when assessing loneliness as there

is evidence to suggest that individuals who live alone are more likely to feel loneliness.

From 1.4%-2.7% in men living with partners to 10-20% of individuals living alone feeling

lonely. (Beutel et al.) Loneliness has been shown to have a non-linear 'U' shaped

distribution across the population with a 9% incidence of loneliness for those aged 55

and above and 25 and below. (Victor and Yang)

Loneliness in older people has also been associated with negative health consequences

from both a mental and physical health perspective. (Luanaigh and Lawlor) There

is evidence linking loneliness to depression. Loneliness has also been linked to

detrimental impact on blood pressure, sleep, immune stress responses and cognition

over time in the elderly. Loneliness has also been linked to generalized anxiety, panic

attacks and suicidality. Suicidal ideation sees a dramatic increase in lonely individuals

with a rise from 6% to 42%. (Luanaigh and Lawlor)

CHAPTER 2: LITERATURE REVIEW

2.1 Effects of aging

When describing the effects of aging on older adults, it is essential to note that there is a wide variance in the impact on different individuals. Aging is not a universal phenomenon that can be described to affect all individuals similarly and at the same periods in their lives. However, declining physical and mental abilities can have a dramatic effect on the usability of technological devices for older adults. Some of the effects of aging that can have a detrimental impact on the usability of technological devices for older adults include the following:

- **Vision:** With increased age, there is a loss in static and dynamic visual acuity, as well as a reduction in the range of visual accommodation, a loss of contrast sensitivity, decreases in dark adaptation, declines in color sensitivity, and heightened susceptibility to problems with glare. Such visual decrements may make it harder for older adults to perceive small elements on a display (e.g., single soldiers in a real-time strategy game), to read small print instructions or captions, or to locate information on complex screens. (Ijsselsteijn et al.)
- **Hearing:** Hearing loss is primarily caused by exposure to loud noises. However, older adults can find it harder to hear high pitched sounds. (Web Accessibility for Older Users: A Literature Review)

- **Motor Skills:** Motor Skills can decline as individuals age. Some of the problems associated with a decline in fine motor skills include decreased speed of movement, a reduction in strength and endurance, changes in balance and coordination, a decline in the ability to maintain constant movement, and loss of flexibility. (Ijsselsteijn et al.)

- **Cognitive:** Changes in cognition related to age are also likely to have a large impact on the usability of technology by older adults. Cognitive processes that may decline with age include attention, working memory, problem-solving and reasoning, and memory encoding and retrieval. (Ijsselsteijn et al.)

2.2 Design guidelines- Designing for older adults

Significant work has been done to establish guidelines for designing digital products for older adults. Some recommendations include:

- *Text:* Using large text sizes with the option of increasing the text size if needed. It is recommended to allow users to undo these changes a single click. It is also recommended to define text sizes in terms of the percentage of containers as opposed to absolute point size to ensure the scalability of font. ("Developing Websites for Older People")

- **Sufficient time:** Some older adults can take longer to read text and complete tasks due to declining vision dexterity or comprehension. WCAG guidelines recommend allowing users to turn off or adjust time limits or eliminate the need for time limits

altogether. ("Developing Websites for Older People")

- **Color and Contrast:** Older adults can lose contrast sensitivity and experience a decline in color perception and acuity. WCAG guidelines recommend not using color as the only means of conveying information and to maintain a minimum contrast ratio of 4.5:1. ("Developing Websites for Older People")

- **Consistent navigation and labeling:** Many older adults require navigation and labeling to be particularly clear due to declining cognitive and visual abilities. WCAG 2.0 guidelines require that there be multiple ways to locate a webpage within a set of web pages.

- **Instructions and input assistance:** It can be difficult for older adults to understand the requirements of forms and other transactions. WCAG 2.0 guidelines require that "labels or instructions are provided when content requires user input." ("Developing Websites for Older People")

2.3 Child Development

Milestones of growth

Developmental milestones are physical or behavioral indicators of the growth of children. Some of the categories of developmental milestones include Social and emotional, Language and communication, Cognitive and Movement. Some developmental milestones for different age groups are listed below. (CDC; Parten)

- 1 year: Can stand with support (for ex. Holding furniture), can babble 2 or 3 words repeatedly, can understand and respond to simple commands.

- Two years: Can run and walk up and downstairs, Can join 2-3 words into sentences.

- 3 years: Can imitate hand movements, speak in complete sentences, and ask questions.

- 4 years: Can skip on one foot, fluent speech with few infantile substitutions, can dress with assistance

- 5 years: Can skip and hop on both feet, can control balance not obtained at 3-4 years of age, can dress alone.

- 6 years: Begin to gain muscle mass and develop fine motor control skills although some clumsiness persists. They can carry out adult-like conversations and are inquisitive about everyday events.

- 7 years: Well developed hand-eye coordination. Vocabulary numbers a few thousand words.

- 8 years: Good finger control and increased endurance and strength. Can enjoy reading and understands how opposites work.

- 9 years: Manual dexterity and hand-eye coordination are well developed. Capable of concentrating and resuming a task after an interruption.

- 10 years: Capable of demanding motor/endurance tasks like bicycling and team sports. Begin to understand right and wrong instead of good and bad.

- 11 years: Better ability to use logic and debate others and better ability to make decisions.

While these milestones indicate a general pattern of child growth and development, it is important to note that not all children will develop at the same rate. While some children skip markers entirely, others might take a little longer to reach them.

2.4 Prevalence of Depression and Anxiety in Children

In the age group of 3-17 years, 7.1% were reported to have anxiety problems, 7.4% had behavioral/conduct problems and, 3.2% had depression. The prevalence of these issues increases with age, with the highest reported levels in the age group of 12-17. Among children aged 3-17 years, 7.1% had current anxiety problems, 7.4% had a current behavioral/conduct problem, and 3.2% had current depression. (Ghandour et al.)

CHAPTER 3: MARKET ANALYSIS

Research was done to analyze the existing products in the market that attempt to help connect people across distances. There are multiple commercially available products and services that try to do this, particularly within the iOS and Android App ecosystems. There are also some products that attempt to solve these problems with flashcards and other paraphernalia. To aid in organization, these products were divided into the following categories:

- **Physical Products:** Products, where a majority of the interaction was physical and did not depend on the necessity of screens or User Interface element, were categorized as Physical Products
- **Digital Products:** Products that relied primarily on screens and User Interface elements were categorized as digital Products
- **Physical + Digital Products:** Products or services that were equally split between screens and tangible products were categorized in the Physical + Digital category.

3.1 Physical Products
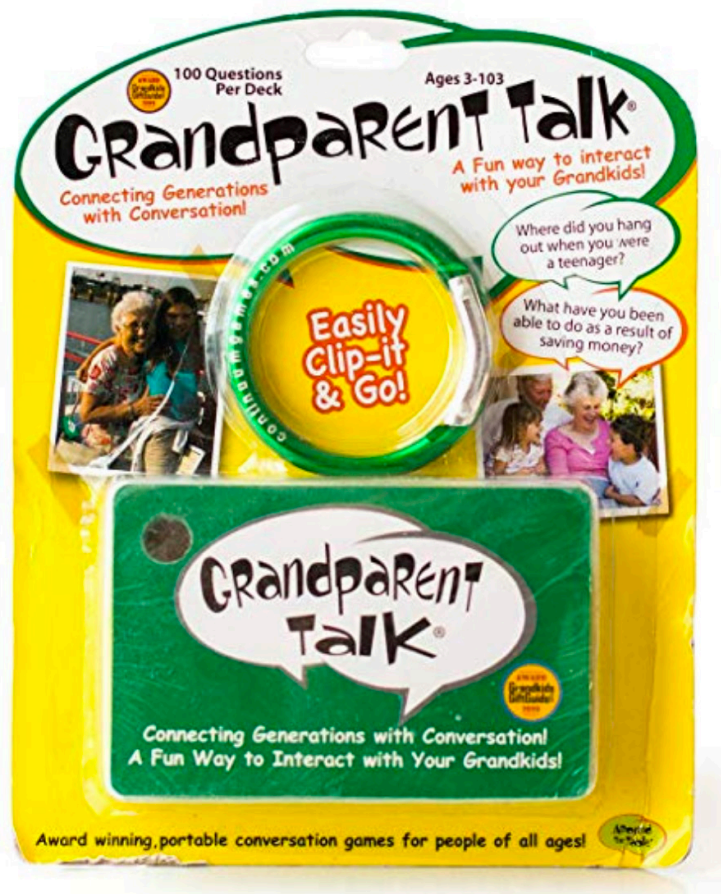
Figure 3.1: Grandparent talk by Continuum games

Grandparent Talk: According to the website description Grandparent Talk is "Fun,

Portable conversation game to connect grandchildren and grandparents! 100 fun

question cards attached to round carabiner clip for use anywhere – at home, at a

restaurant, in the car, on vacation" (Grandparent Talk Continuum Games) Grandparents

talk works as a conversation starter allowing by giving grandchildren a set of questions

they can ask their grandparents.

Letters: Multiple attempts have been made to use letters as a medium to facilitate conversation between grandparents and grandchildren. One of these was "Grandconnect, a letter writing kit that included prompts. According to an article in the Tribune, Grandconnect is a letter-writing kit that consists of two notebooks, one of which is given to the grandparent and the other to the grandchild. The kit includes prompts for writing letters, asking both grandparent and child to share the stories of their lives with each other." (Vanoverbeke) While letters serve as an excellent means of one to one communication between individuals, their popularity has been on the decline in recent times.

Phone calls: Phone calls are a widely used medium to communicate across distances. Phone calls provide a quick and relatively accessible means for communication. However, they do not allow for rich communication as you can only hear the other person. Phone calls can be less attractive and engaging, particularly when it comes to early relationship building with younger audiences.

In-Person Activities: A rather diverse set of possibilities that include vacations, birthdays, holidays, sporting events, and dinners amongst others. While these are a great way to communicate and build relationships, they do not work for everyone as some people are separated by too much distance to meet frequently.

3.2 Digital Products

Video Calls: Multiple video calling services facilitate communication between groups of people. Skype, Zoom, and House Party are examples. Skype is a video calling service by Microsoft that is available on Windows, Mac, Android and iOS devices. According to their website "Skype makes it easy to stay in touch" (Skype | Communication Tool for Free Calls and Chat) Skype allows for two way communication that is both auditory and visual. However, Skype and other video calling services can sometimes be technically challenging for the elderly. These services also require some initiative on the part of the users to be effective.

Moment Garden: Moment Gardens website description states that it lets you "Save and privately share your child's precious moments with the people who matter most. It's fun, secure and easy as email." (Moment Garden) It is an Android and iOS app that allows users to create a "walled garden" where they can upload photos and videos and share them with family and friends.

Social Networking Sites (SNS): There are a multitude of different social networking sites available for use as of this writing. While some of these are meant for mass adoption, others have been built with a specific purpose for a more niche market. "What makes social network sites unique is not that they allow individuals to meet strangers, but rather that they enable users to articulate and make visible their social networks." (Boyd and Ellison)

Social Networking Applications: There are quite a few mobile-only social networking platforms that are available. These include Instagram, Snapchat, TikTok, amongst others. A lot of Social Media Applications allow users to broadcast information to multiple people simultaneously. Applications like Facebook and Instagram allow users to "like" or react to posts allowing for quick ways of expressing emotions.

Mago TV: Mago TV is a Japanese service that allows users to broadcast photos and videos directly onto the television of the grandparents. Built specifically to counter technological barriers, Mago TV has a standalone receiver that plugs into the TV via HDMI cable and allows for effective one way communication.

Digital Frames: Multiple different digital frames exist in the market that allows users to broadcast or upload media to a standalone device that then periodically displays the media. These serve as the digital equivalent of photos displayed in a photo frame.

3.3 Physical + Digital Products

Iyagi: Iyagi was a student project at Carnegie Mellon University that developed a projector and app experience to help parents initiate the bedtime routine to put their children to sleep. The proposed system relied on multiple projectors spread around the house that could be used to aid in storytelling and help make a gentle transition into sleep time.

3.4 Evaluation of Existing Products

To help verbalize design considerations and needs, the researcher developed a set of evaluation criteria along with a scale of importance. The metrics were all ranked on a score of 1-5 where 1 had the least importance, and 5 had the most. (Figure 3.1)
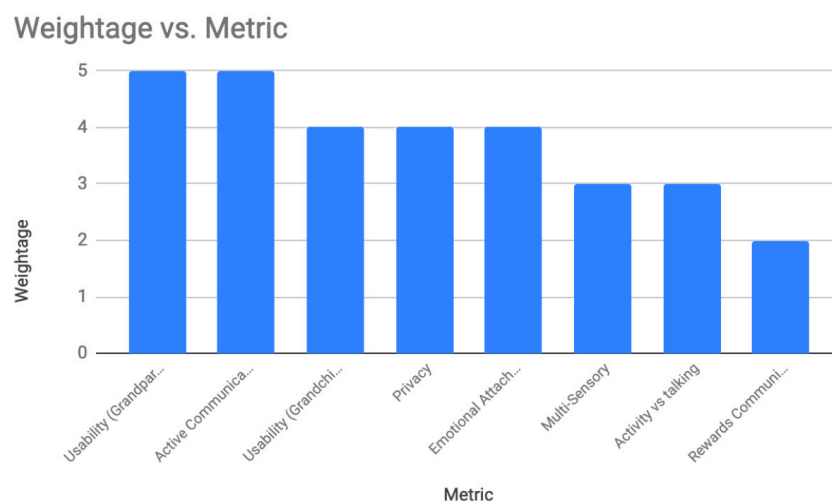
Figure 3.2: Metrics used to evaluate existing products/services

Usability for Grandparents (5): "Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process." ("Usability 101") Usability for grandparents was deemed extremely important as a product that would not be usable for the elderly would not serve its function.

Active communication (5): Active communication was defined as a measure of how personal communication was between the users. Likes on SNS were given the lowest score for active communication as they are usually low effort and do not communicate

much beyond basic appreciation.

Usability for Grandchildren (4): Children, in general, appear to have a fair understanding of touch screen devices. (Oliemat et al.) and are generally comfortable with technology. For this reason, usability for children was given a slightly lower priority score than usability for grandchildren.

Privacy (4): Privacy was given a relatively high score as there are Federal regulations in place that specify how and when information can be collected from children along with what kind of data can be collected.

Ability to create emotional attachment (4): The ability to create an emotional attachment between two users using the product/service was considered an essential element of a successful design as there is a need to form strong connections between grandparents and grandchildren.

Multi Sensory (3): How many senses a product/service engages was considered an important element of the entire designed experience.

Activity-based as opposed to talking only (3): Products and Services that were activity-based as opposed to only talking were given a higher score as an increase in screen time and reduction in activity, mainly physical activity has been linked to an increase in childhood obesity. (Robinson et al.)

Reward for communication (2): It was also considered important, albeit a lower priority to reward communication in some manner, particularly for the younger generation.

Based on these metrics, a Pugh matrix was used to evaluate the existing solutions in the market. The evaluation and metrics developed were further used to inform design

Metric	Weight	Mago TV	W. Score	Iyagi	W. Score	Video Calls	W. Score	Phone Calls	W. Score	Letters	W. Score	Photo /Scrapbooks	W. Score	Moment Garden	W. Score	Aura Frame	W. Score	Granparent Talk	W. Score
Usability (Grandparents)	5	10	50	6	30	5	25	10	50	10	50	7	35	6	30	10	50	7	35
Active Communication	5	4	20	10	50	5	25	4	20	10	50	8	40	7	35	1	5	10	50
Usability (Grandchildren)	4	1	4	8	32	5	20	10	40	7	28	7	28	7	28	1	4	10	40
Privacy	4	10	40	10	40	4	16	7	28	7	28	8	32	4	16	2	8	8	32
Emotional Attachment	4	5	20	7	28	5	20	4	16	8	32	5	20	5	20	4	16	7	28
Multi-Sensory	3	2	6	10	30	1	3	1	3	5	15	6	18	4	12	3	9	5	15
Activity vs talking	3	5	15	10	30	2	6	1	3	1	3	7	21	6	18	3	9	3	9
Rewards Communication	2	1	2	2	4	1	2	2	4	2	4	4	8	5	10	3	6	6	12
Total			157		244		117		164		210		202		169		107		221

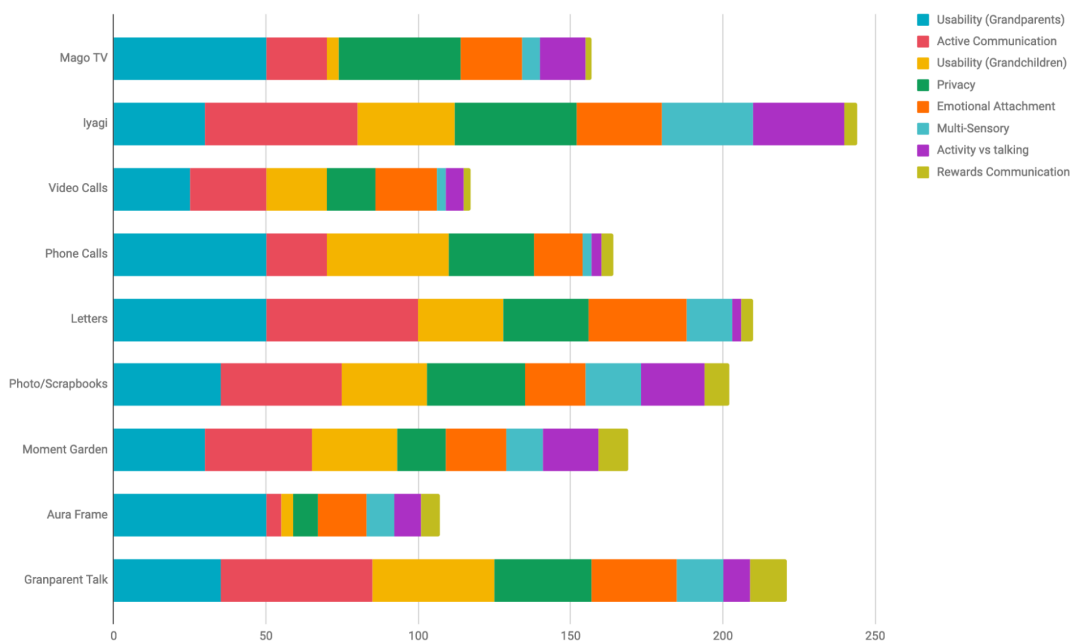Figure 3.3: Pugh Matrix used to evaluate ideas

Figure 3.4: Graph depicting values from Pugh Matrix

decisions taken through the course of the design and development phase of this project.

Figure 3.4 shows that Iyagi and Grandparent Talk came out on top of these rankings as they were both platforms that promoted active activity-based communication (Rich in-person conversations for Grandparent Talk and storytelling across different rooms in the case of Iyagi).

2X2 Matrix

To further analyze these products, they were placed on a 2X2 matrix with the X-axis moving from analog to technological and the Y-axis moving from passive to active.
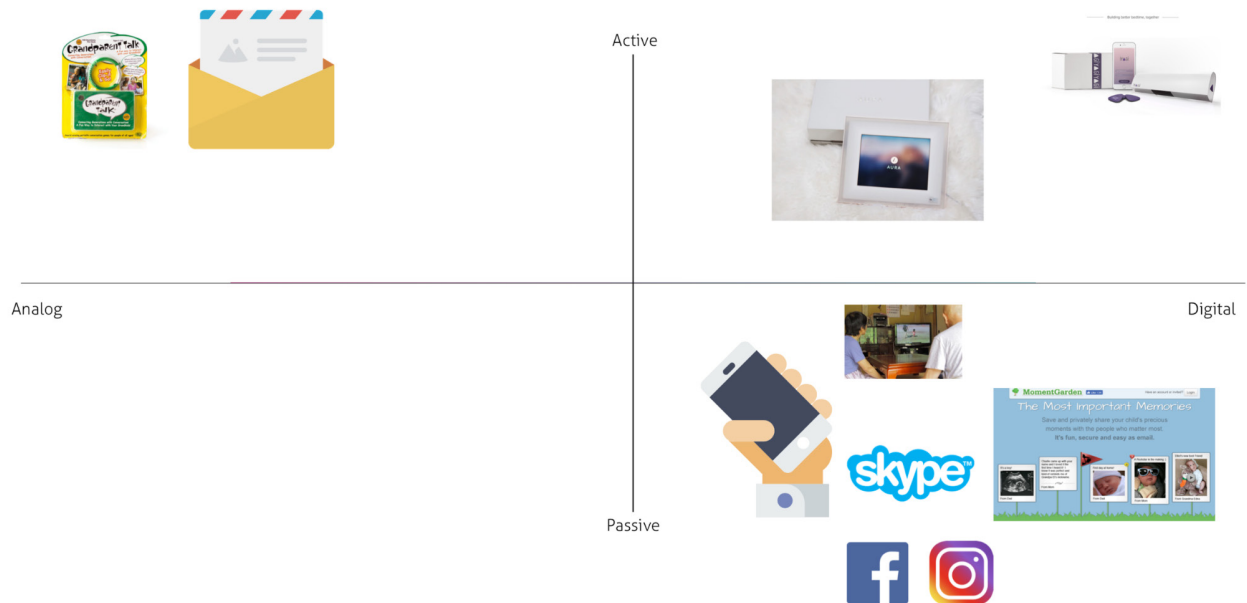
Figure 3.5: A 2X2 matrix used to evaluate existing products

It was noticed that a majority of competing products were placed in the 4th quadrant. If the Analog vs. Digital is looked at as a snapshot through time, then it appears that social networking sites have meant more passive communication where individuals are

communicating with more people. However, the communication, because of the nature

of the platform, has more breadth than depth.

CHAPTER 4: PROJECT BRIEF

4.1 Persona Maps

"Persona mapping is the creation of fictional, but realistic profiles of our target customers. They reflect characteristics like personal attributes, goals, motivations, attitudes and more." (Williams) Fictional personas were created to help visualize the target demographic and to communicate the researcher's understanding of their values, needs, and aspirations. Persona Mapping was used primarily as a tool to ultimately aid in the creation of the design brief. The personas created are listed in the following two figures. (Figures 4.1 and 4.2)

Paul Middleston
Recently Retired (former banker)

Age: 67 Years
Gender: Male
Location: Pullman, WA
Family: Divorced, lives alone with a cat
Hobbies: Golf, cooking, bird watching, chess
Mobile: iPhone 7 Plus
Apps Frequently Used:

Quote

"At 20, we worry about what others think. At 40, we don't care what they think of us. At 60, we discover they haven't been thinking of us at all."

Figure 4.1: A fictional persona map created for a grandparent

Sarah Middleston
Elementary School Student

Age: 7 Years
Gender: Female
Location: Seattle, WA
Family: Parents, younger brother & dog
Hobbies: Painting, soccer, social media,
Mobile Photo: Moto G6
Apps Frequently Used:

Quote

"You don't have to be perfect to be amazing!" 💁🏻

Figure 4.2: A fictional persona map created for a grandchild

4.2 Journey Maps

"In its most basic form, journey mapping starts by compiling a series of user actions into a timeline. This narrative is condensed and polished, ultimately leading to a visualization." ("Journey Mapping 101") A day in the life" journey maps for the two personas were created to aid in the visualization of the critical points of intervention. These artefacts were intended as a way to externalize the researcher's understanding of the lives of the target audience and to help in the development phase of the project. (Figures 4.3 and 4.4)
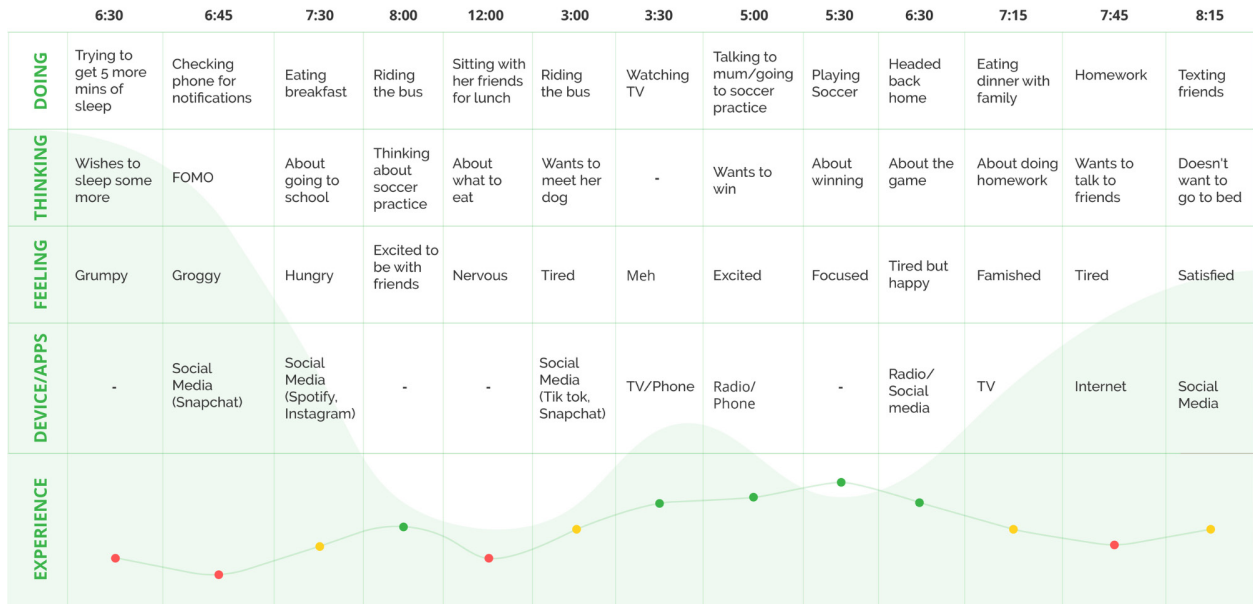
A day in the life of Sarah Middleston

	6:30	6:45	7:30	8:00	12:00	3:00	3:30	5:00	5:30	6:30	7:15	7:45	8:15
DOING	Trying to get 5 more mins of sleep	Checking phone for notifications	Eating breakfast	Riding the bus	Sitting with her friends for lunch	Riding the bus	Watching TV	Talking to mum/going to soccer practice	Playing Soccer	Headed back home	Eating dinner with family	Homework	Texting friends
THINKING	Wishes to sleep some more	FOMO	About going to school	Thinking about soccer practice	About what to eat	Wants to meet her dog	-	Wants to win	About winning	About the game	About doing homework	Wants to talk to friends	Doesn't want to go to bed
FEELING	Grumpy	Groggy	Hungry	Excited to be with friends	Nervous	Tired	Meh	Excited	Focused	Tired but happy	Famished	Tired	Satisfied
DEVICE/APPS	-	Social Media (Snapchat)	Social Media (Spotify, Instagram)	-	-	Social Media (Tik tok, Snapchat)	TV/Phone	Radio/Phone	-	Radio/Social media	TV	Internet	Social Media
EXPERIENCE													

Figure 4.3: A fictional journey map created for a grandchild

A day in the life of Paul Middleston

	7:00	9:00	10:00	10:30-1:00	1:00	2:00	3:00	5:00	6:00	7:00	7:30	9:00	9:05	12:00
DOING	Making Coffee	Eating breakfast, watching the news	Feeding The cat	Watches TV, Golf re-runs	Heats Lunch	Plays Candy Crush	Goes to Facebook	Goes for evening walk	Goes to a local chess club	Watches TV	Makes Dinner	Call son	Watches TV	Goes to sleep
THINKING	What to eat	About rise crime in WA	Checking if cat has eating enough	-	Nostalgic, not used to eating lunch alone	About getting a high score	About friends & family	About how the neighbou-rhood has changed	About different game strategies	-	About what to make	About catching up	About son and grandkids	About forgetting grocery shopping
FEELING	Neutral	Unhappy with the world	Joyful	Meh	Sad	Ambitious	Lonely	Satisfied	Happy	Neutral	Excited	Happy	Sad	Tired
DEVICE/APPS	TV	TV	-	TV	TV	Mobile Phone	Laptop	-	-	TV	TV / Phone	Phone	TV	TV
EXPERIENCE														

Figure 4.4: A fictional journey map created for a grandchild

4.3 Identification of Problem Areas

Before the creation of the final design brief, key problem areas that could be possible intervention points were identified. These insights helped formulate the brief and helped define the key features that the designed solution must satisfy for a holistic experience. Some of the key problems identified included the following:

Alienation of the elderly: A qualitative study of alienation amongst the elderly in Hong Kong listed three primary reasons for perceived alienation amongst the elderly population. These included a perceived lack of sufficient care for older people, a growing distance between society and older people. And older people's disintegrating identity in society.

Growing depression amongst children: Research has indicated that the diagnosis of depression in children has increased over time. Diagnosis of depression in children between the ages of five to seventeen has increased from 4.7% in 2007 to 5.3% in 2011–2012. (Bitsko et al.) Both depression and anxiety have been associated with an increase in the prevalence of other health conditions and the impact on children and families.

4.4 Design Brief

Based on findings during the literature review and other explorations, a design brief was developed to help verbalize key goals and design directions. The brief was used as a means to communicate key research findings and to aid in the brainstorming and ideation process.

The design brief was as follows:

The aim of the project is to foster new relationships and enable communication by creating a platform for play where stories, thoughts, and ideas can be shared across physical and generational distances by:

- Creating a platform to enable grandparents to form relationships with their grand-kids, across distances.
- Creating multiple avenues for interaction to encourage communication and play between the users
- Being activity focussed as opposed to image/text sharing only
- Serving as an aid to parents in the task of parenting their children.
- Focussing on active forms of communication as opposed to passive.

Four "How Might We" statements were also developed to refine the brief further and to help communicate the value proposition of the project.

- How might we connect Grandparents and grandchildren across distances?
- How might we help Grandparents share their experience and skills?

- How might we create a space for child-led play instead of structured activities?

- How might we create a platform that grows with children?

CHAPTER 5: DESIGN AND DEVELOPMENT

5.1 Initial Brainstorming

Initial brainstorming was conducted to help short-list some ideas that could be used as a starting point for the design of the platform. Some of these included the following:

- **A planning and scheduling platform:** A platform to allow grandparents and their children to schedule calls and videos on a semi-regular basis. The idea behind this was that although both user groups would like to talk to each other, scheduling times that work for all users can be difficult.

- **A grandparent-grandchild phone app:** A mobile app that allows for direct communication between grandparents and grandchildren. This would serve as a personalized connection hub with a simplified User Interface that would allow for seamless communication.

- **A storytelling platform:** An interactive application that would allow grandparents to tell stories to their grandchildren. The grandparents would have the ability to record themselves reading out stories, and this would allow for communication between the two user groups.

- **Interactive Movies:** A set of video-based media with an interactive element that the two users could watch simultaneously, despite being in two different physical locations. This would serve as a shared virtual space that they could meet in.

- **Imaginary House:** A house based in a virtual space that the two users could spend

time in. The intention of this platform would be to allow the grandparents to pass on some skills in a virtual environment, i.e., a house that needs taking care of.

- **A new world and friend:** Similar to the "Imaginary House" mentioned above, except the world as a whole in this case. This would allow the two users space where they could collaborate on adventures in a new world. This would allow for freeplay and allow exploration of a range of different concepts.

- **Tactile feedback to teach pottery/other skills:** A platform that would allow for tactile feedback with the use of gloves or other such mechanisms and would allow for the grandparents to pass on skills remotely.

- **An Augmented Reality platform:** An augmented reality platform that allows for free play and allows the grandchildren to explore different concepts through either a mobile or tablet app.

5.2 Value Horizon Matrix

The Value Horizon Matrix is a qualitative evaluation tool that can be used to evaluate a range of ideas and sort them between them. The two categories used on the X and Y axis were "Customer Value" and "Innovation" respectively. As such, The Y-axis ranged from Low customer value to high customer value, and the X-axis ranged from incremental innovation to big, bold idea. The four quadrants were labelled Experience Evolution, Disruptive Potential, Misguided Efforts, and Low Hanging Fruit, respectively. Ideas in the Disruptive Potential quadrant were selected for further development.
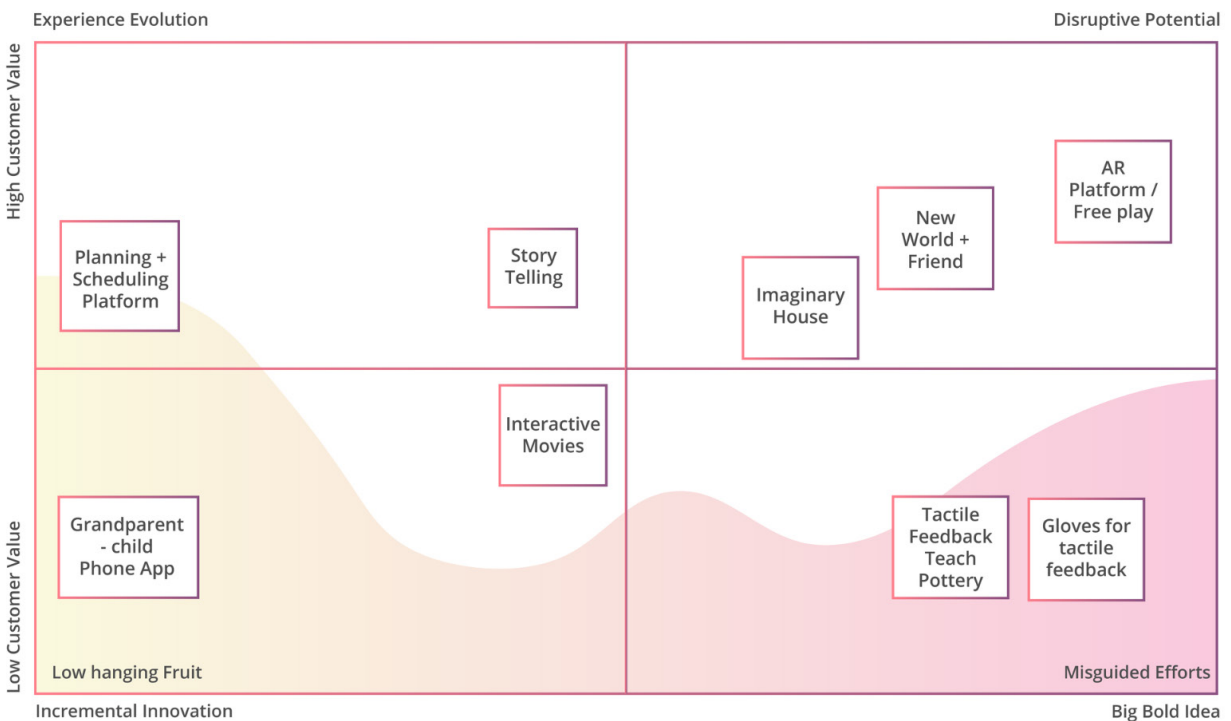
Fig 5.1 : Value Horizon Matrix depicting idea selection criteria

5.3 Direction One

Based on the value horizon matrix, the first idea that was further developed was an

AR platform for freeplay. Initial user flows and some visuals were created to develop

the idea and allow the researcher to receive some qualitative feedback on it. The idea

developed included a "frame" which would consist of markers for a mobile camera.

(Figure 5.2) When the application for the platform would be opened, it would turn on the

mobile phone camera and create visuals to fill in the frame. The child could then interact

with this platform via their mobile device.
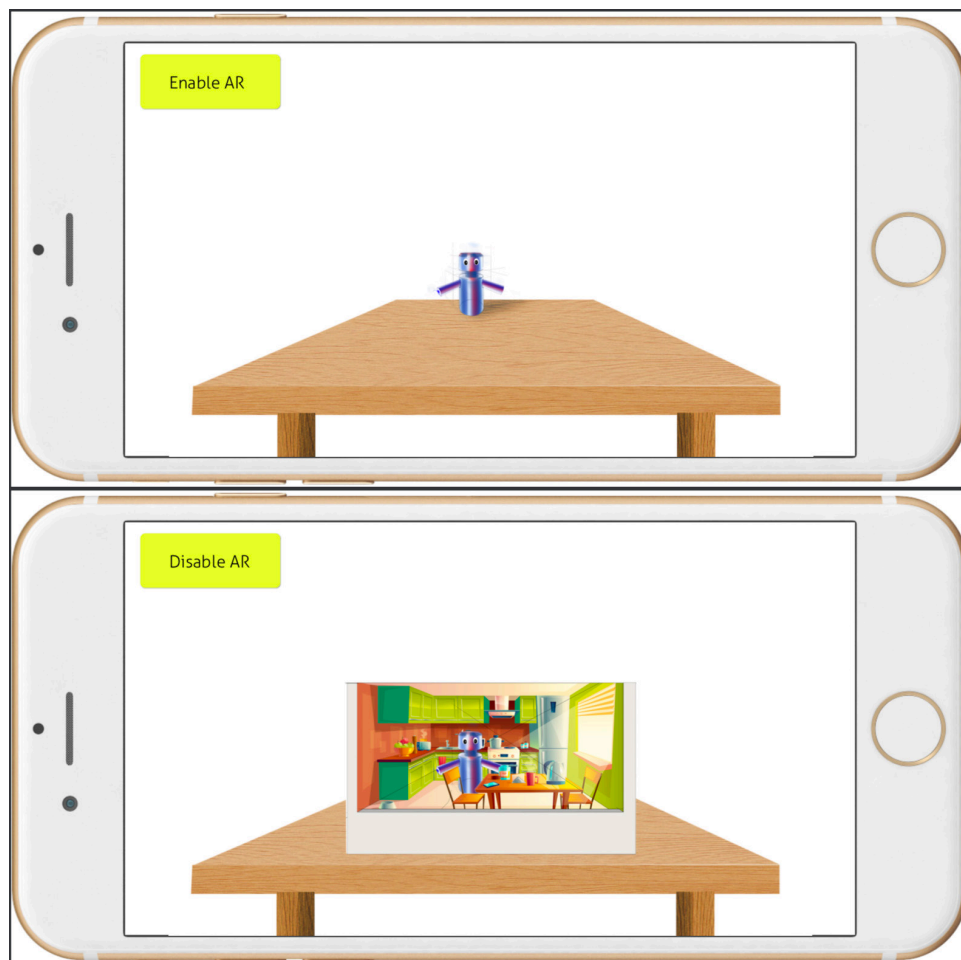
Figure 5.2: (Depiction of Augmented reality platform)

Due to early informal feedback, it was decided that the augmented reality platform was infeasible for the following reasons:

Tactile feedback: The Augmented reality platform relied primarily on a two-dimensional screen. This provided minimal opportunity to provide users with tactile feedback and was considered problematic as the need for tactile feedback along with a multi-sensory experience was considered an essential part of the initial brief.

Fine motor skills: As the fine motor skills are still being developed in children, an augmented reality platform would be difficult to use. The augmented reality platform would require coordinated movement involving both hands and interaction with minute elements on the screen, making it infeasible for the target audience.

5.4 Direction Two

The second direction that was explored was a mixed reality platform that would allow for physical interaction with certain elements. The idea behind this direction was to create a shared space that the grandparent and grandchild could explore simultaneously.
To illustrate this idea an initial user flow was created which allowed the researcher to explore possible interaction spaces and verbalize the activities that could be conducted via the platform.

5.5 Elements of the system

The proposed platform included the following elements to create a holistic environment for grandparent-grandchild interaction. (Figure 5.3)

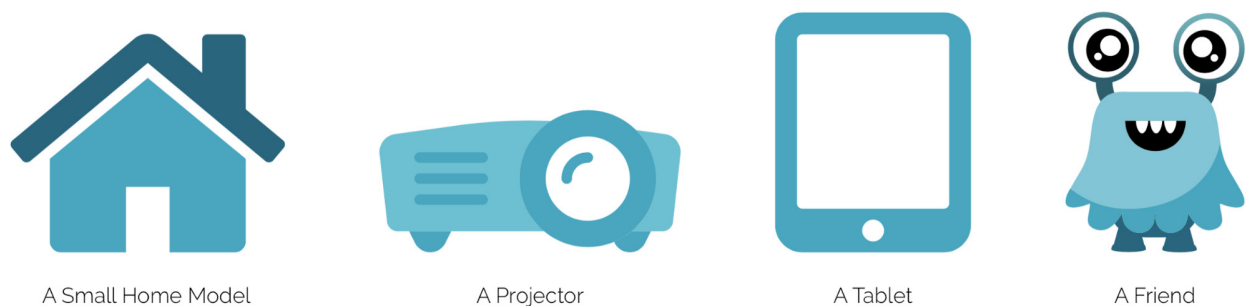| A Small Home Model | A Projector | A Tablet | A Friend |

Figure 5.3: Elements of the system

- **A physical house:** A scale model of a house that would allow for interaction. The child would have the option to change the appearance of the home, either virtually or by moving furniture around.

- **A Projector:** A projector that projects onto the physical model of the house. The idea allows for interaction in either the digital or physical space. The projector would need to be placed a certain distance away from the house and project different environments onto the house.

- **A character:** A character that serves as the primary motivator for the child to interact with the platform. The character would serve as a virtual and digital pet that the child needs to take care of. A physical model of the character would live in the house, and a digital version would exist within a tablet application.

- **Tablet Application:** A mobile application that would allow the child and grandparent

to communicate. The app also allows the child to interact with the projector-house

system and change the visual appearance of the house.

5.6 Possible Interactions

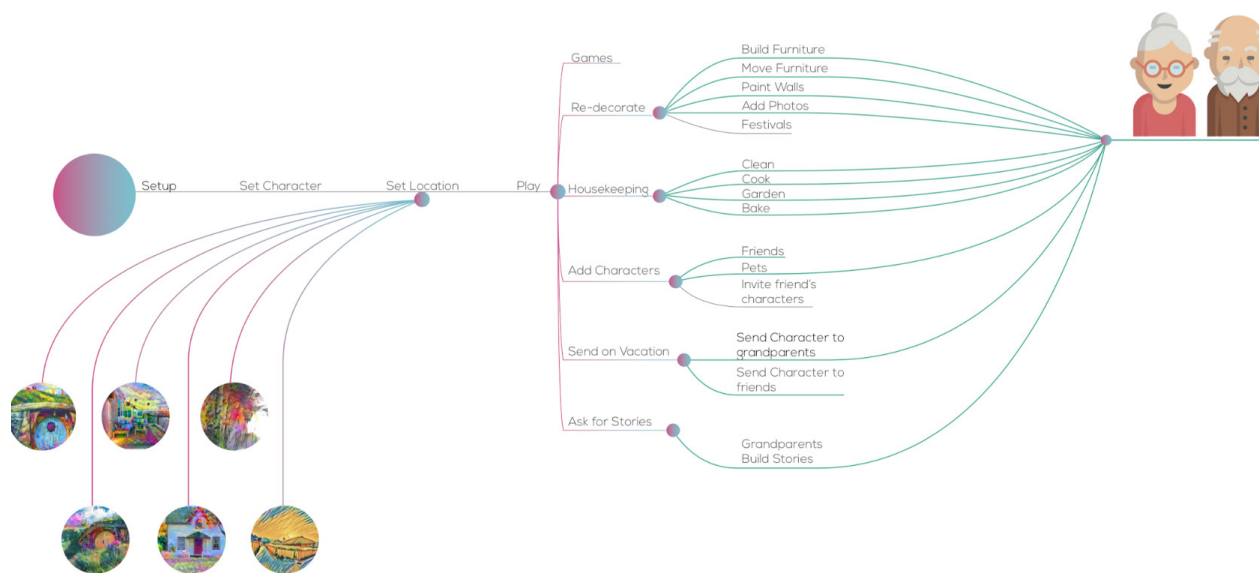Some of the interactions decided on included the following (Figure 5.4)

Figure 5.4: Possible interaction points

Re-Decoration: Redecorating the house to change various elements including building

and moving furniture, painting walls and adding wallpapers, adding photos from real life

and improving the appearance of the home-based on seasonal activities like Christmas

and Thanksgiving.

Housekeeping: Performing general periodic maintenance on the house including

cleaning (sweeping, vacuum cleaning, etc.), cooking meals for the character, gardening

(planting plants, watering, de-weeding, etc.) and baking.

Adding characters: Adding pets for the character, inviting friends' characters over to their house to create a richer environment.

Send on vacation: The option for the child to send the character to their grandparents. The grandparents would have the opportunity to take photos on their mobile device in which the character would appear. This allows for two way interaction and photo and video sharing.

Asking for stories: The grandchildren would have the option to ask grandparents for stories. The grandparents would then have the opportunity of either reading out stories from scratch and also have the option to read out auto-generated stories involving the character for the child.

5.7 Physical Experience Development

Various iterations of both the character and house were developed to create a design platform that allowed for different levels of interaction. The parameters that were considered necessary during this phase included the following:

Projection Accessibility: The shape of the house must allow for the projector to cover the maximum surface area possible to allow for as much flexibility as possible with the projector.

Breaking away from traditional images: It was considered essential to break away

from the conventional model of the doll-house as it was considered to be necessary to create a new language for this platform.

Figure 5.5, 5.6 and 5.7depict the various alternatives considered for the final design prototype.

Figure 5.5: Low Fidelity prototypes for testing

Figure 5.6: Low Fidelity prototypes with a projector

Figure 5.7: Various CAD models of house

An egg-shaped variation (depicted in Figure 5.7) was selected as the final version of the design as it broke away from the traditional image of a doll-house. The egg shape would also allow for more exciting projections. The egg-shaped model was further iterated on to refine the design sensibility and aesthetic.

5.8 Digital Experience Development

To create the digital experience, the first step that was undertaken was to develop a possible week of what the interactions with the platform and with grandparents could be. (Figure 5.8)

Figure 5.8: A day in the week

The interactions decided on included the following:

- **Monday:** Make a painting that could then be projected onto the character's room. The grandchild would have the option of creating a painting in the in-app environment that could then be projected onto the house.

- **Tuesday:** Solve a puzzle for the character. The grandchild would have the option to solve a few 2D/3D puzzles along with the character. These could then be projected onto the house, creating a small variation in the environment.

- **Wednesday:** Wash the character's clothes. The clothes that are projected on to the physical model of the camera get dirty over time. The child would have the option to clean these clothes using a virtual washing machine.

- **Thursday:** Make some food for the character. The grandchild would have the option to cook some food for the character. They would do so in a virtual kitchen that would allow multiple steps, including using a stove and cutting vegetables.

- **Friday:** Vacuum the characters house: The house gets dirty over time with visible specks of dust and cobwebs. The child would have the option to clean different spaces in the house with the help of a virtual vacuum cleaner.

- **Saturday:** Buy some new clothes for the character. The grandchild would have the option to buy new clothes for the character. They would have the option to pick from a few different options.

- **Sunday:** Grandparent-Grandchild activity of the week. At the end of the week, there would be a grandparent-grandchild activity that can be used as space for the grandchildren to share their progress over the week. This would also be a space for the grandparents to teach their grandchildren different skills.

This week based model was further developed into a list of all possible interactions within the ecosystem. A point system was added to add a challenge to the activities that the child needed to do. This was developed in the form of mini-games that the grandparents could customize depending on the child's needs. The mini-games included:

Math: Math based mini-games that would ask questions. These were intended to help augment the child's mathematical knowledge and learning in a casual setting.

Language: Language-based games to augment grammar and vocabulary skills

Cognitive: Cognitive based games to help augment the child's spatial and visual skills.

"Just for fun": Fun games that can be played for the mere sake of enjoyment and to keep the child engaged in the platform.

Figure 5.9 illustrates the different options the app has as they interact with the platform on a daily and weekly basis. This was used as a means to communicate the idea and verbalize interaction points.
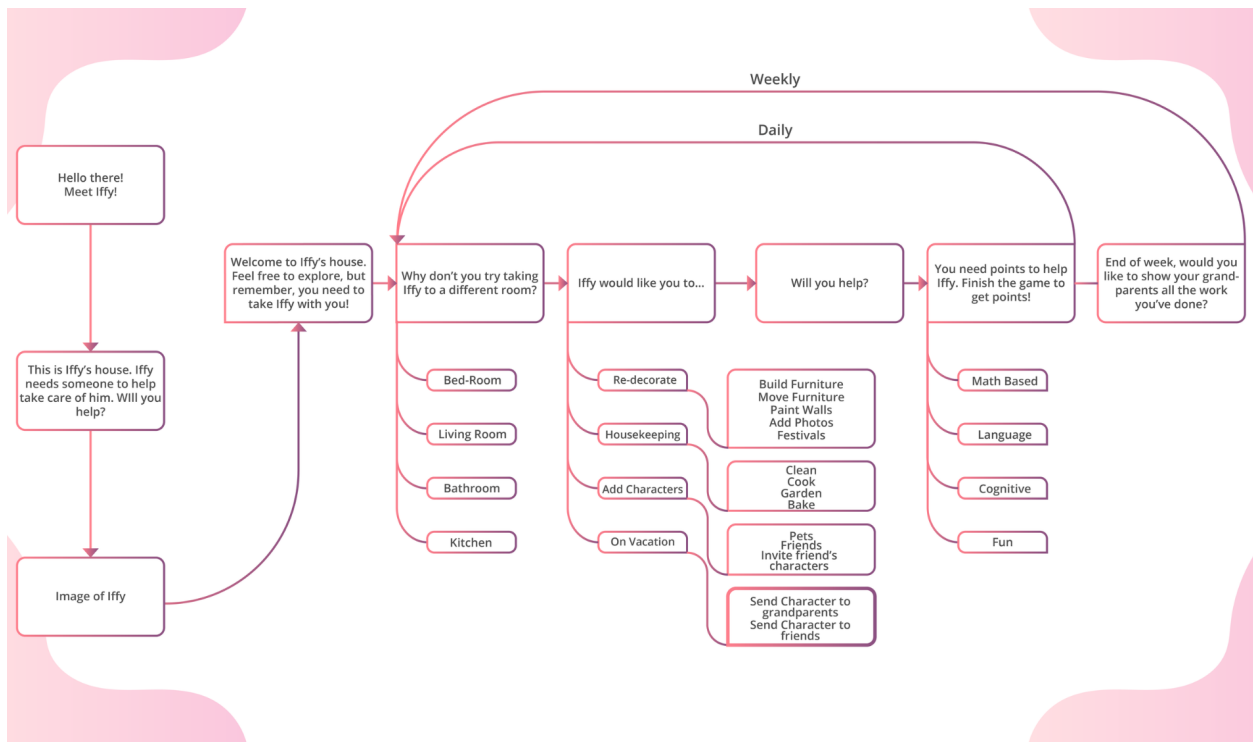

Figure 5.9: A day in the week

A detailed user flow was developed using this model to refine the possible steps on the tablet application. Ovals were used to denote start/endpoints, diamonds were used to indicate decisions, rectangles to denote steps, and arrows to indicate direction. (Figure 5.10)
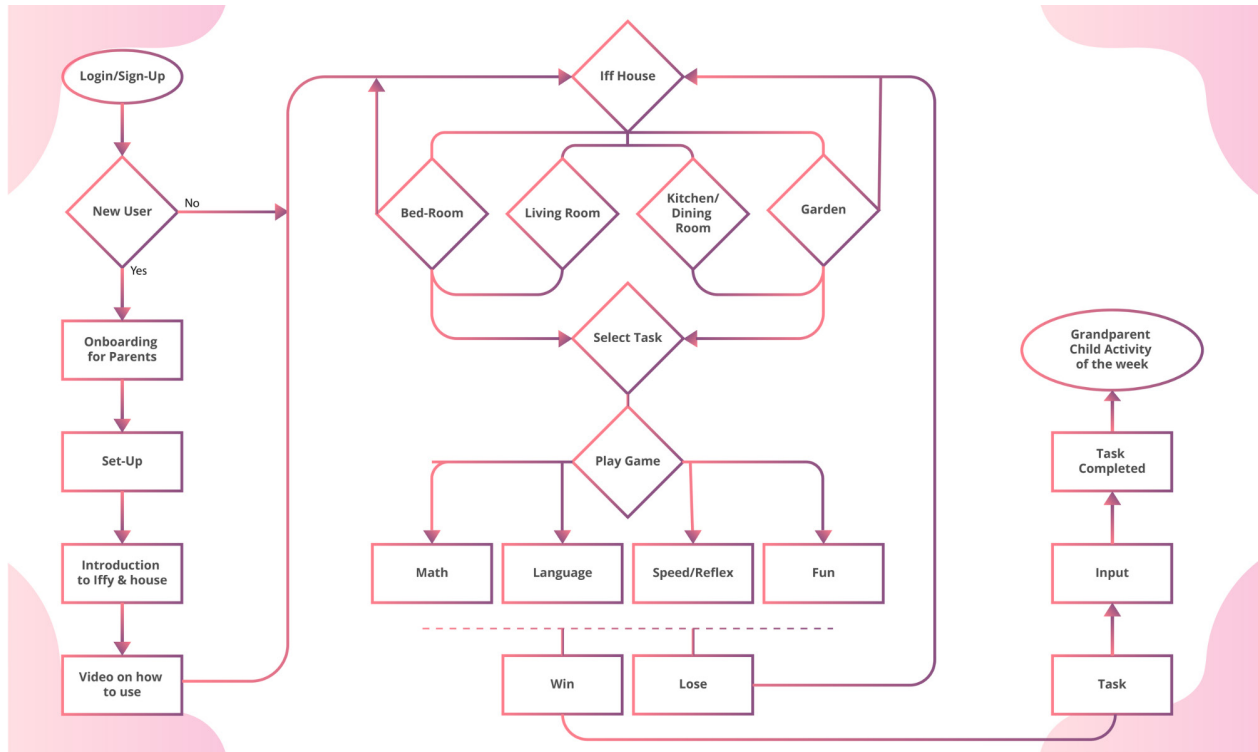
Figure 5.10: User Flow of mobile application

After the initial login, the app would include the following steps:

New User setup: Including creating an account, and introduction for the parents about how to set up the projector along with instructions on creating a shared account with the grandparents.

Character's House: The child would then be taken to an image of the character's house where they would have the option of interacting with it by clicking on a few different rooms. The app would then take the child to these rooms.

Within these different rooms, the child would have the option to pick from a variety of different tasks that the grandparent sets for them.

The child would then be prompted to play some games to win enough points to do the task. Depending on the game, a different number of points would need to be won.

If the child wins enough points, they would then be able to complete the tasks.

All of the tasks mentioned in steps one through five would recur daily. At the end of the week, there would be space for the grandchild- grandparent activity. This would be in the form of a video call where the grandchild could show the grandparents the activities they have conducted throughout the week.

Wireframes were then sketched out using pen and paper to illustrate a few screens of what the application could potentially look like. (Figure 5.11) These wireframes were finally digitized using the Adobe Creative Suite to create a better visualization of the final application. This digitized wireframe was used to create the final version of the mobile application prototype. (Figure 5.12)
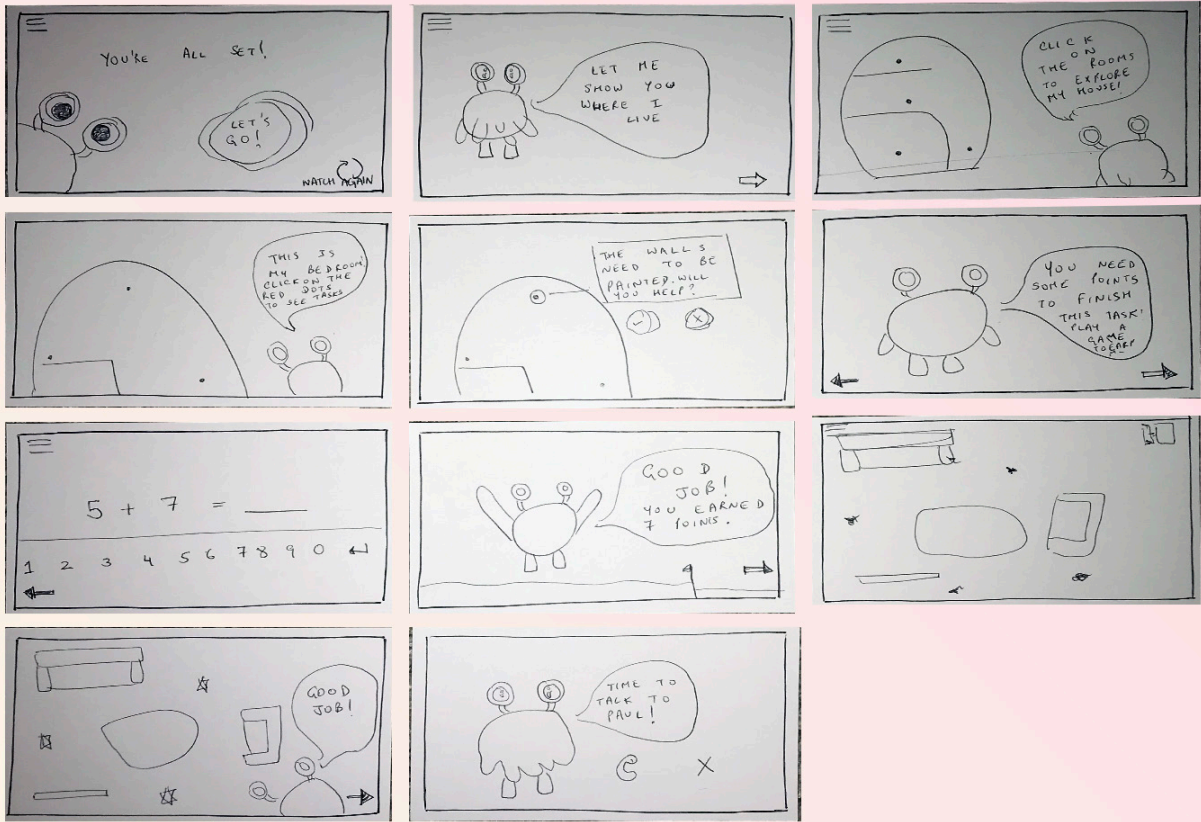
Figure 5.11: Initial wireframes
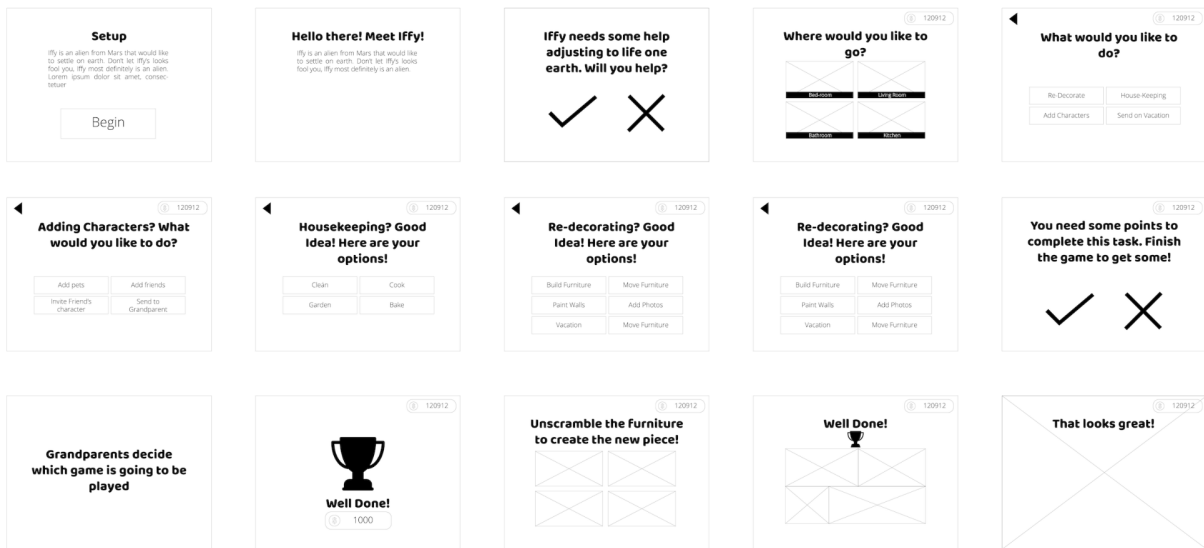
Figure 5.12: Digitized version of wireframe

5.9 Character Development

Multiple iterations of the character were developed to refine the aesthetic and visual of the character. (Figure 5.13)
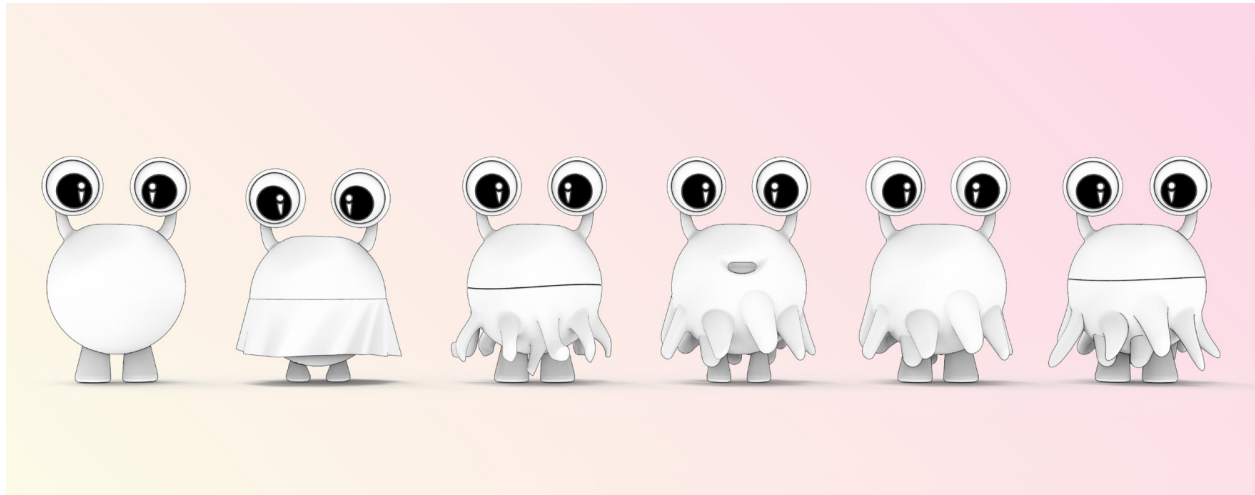

Figure 5.13: Various CAD renders of character

The final character was visualized as an alien that is new to earth and needs to be taken care of by the child. The character was given the name "Iffy" to bolster the perception that the character needed to be taken care of. (Figure 5.14)
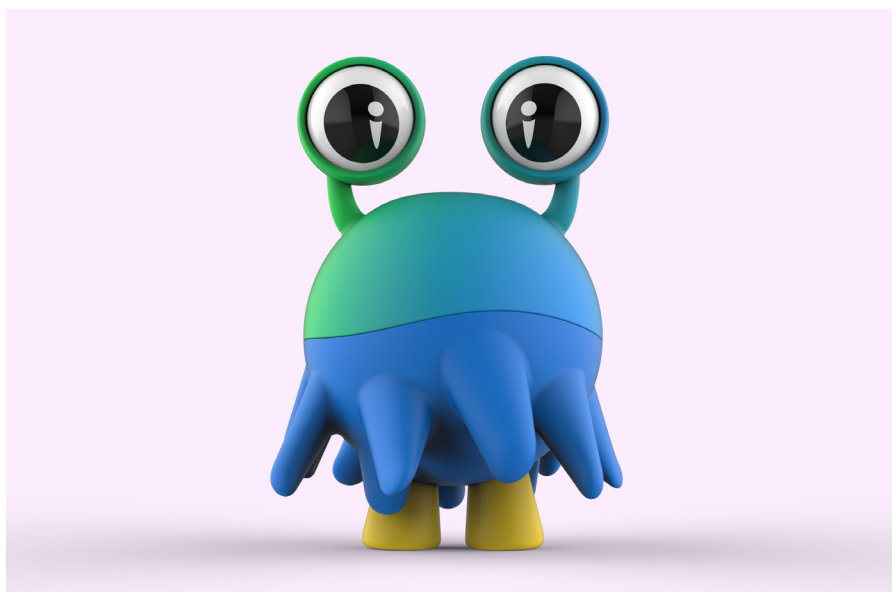

Figure 5.14: Color render of final character

CHAPTER 6: PROTOTYPING

Prototypes of all elements of the system were developed as the last step of the design process to refine the concept further. The house, the mobile app, and the characters were all prototyped using a variety of processes that are included in the following few sections.

6.1 Prototype of house

The house was constructed using Medium Density Fibreboard (MDF). MDF was chosen because of the relative ease with which it can be shaped and finished. The development process for the prototype included a few steps which are listed below.

Computer-Aided Design (CAD): A to-scale CAD model was developed in SolidWorks.

CNC Routing: The CAD model was split into three vertical segments to allow for CNC routing. Two three-quarter-inch sheets of MDF were glued together as the maximum depth the CNC router could be used at was 1.5 inches. A third sheet of MDF was added with a sheet of paper in-between to negate the need for supports while routing.

Hand Finishing: The three different routed blocks were then hand-finished using a variety of tools, including files, sandpaper, needle files, palm-sanders, and belt sanders.

Glue-up: The three blocks were then glued together using wood glue, and further finishing was done to refine the shape.

Spackle and Bondo: Bondo and Spackle were used to fill in any gaps left after sanding. Multiple coats were applied and allowed to dry before the desired finish was

achieved.

Primer and Paint: Primer and white water-based paint was applied as the final finish.

3D printing: All furniture was 3D printed using a fused deposit modeling (FDM) printer.

Spackle was then applied to these prints, and water-based paint was used as the final
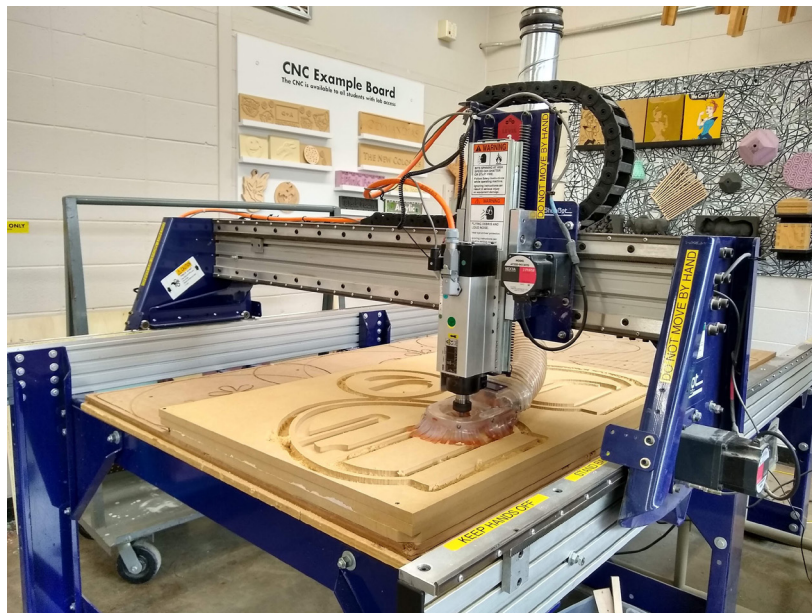
coat.

Figure 6.1: CNC Routing of MDF sheets

Figure 6.2: CNC output

Figure 6.3: Pieces separated using a jigsaw

Figure 6.4: Blocks sanded and glued up

Figure 6.5: Primed and painted prototype

6.2 Prototype of Character

The character was prototyped using 3D printing with a Stereolithography (SLA) printer. SLA was chosen because of the multiple overhanging supports that using an FDM printer would create. The 3D print was done in two parts which were then glued together, sanded, primed and painted. (Figure 6.6)

Figure 6.6: 3D printed character and furniture

6.3 Prototyping Mobile Application

The first part of prototyping the application was to pick a color scheme.

Once the color scheme was decided upon, prototypes were created in Sketch-App (A

UI/UX prototyping tool) to create a visualization of what the final screens would look like.

"Baloo Regular" was used as the display font and "Open Sans Light" was used for the

body text. (Figure 6.7)

Display Font: Baloo Regular
Body Font: Open Sans Light

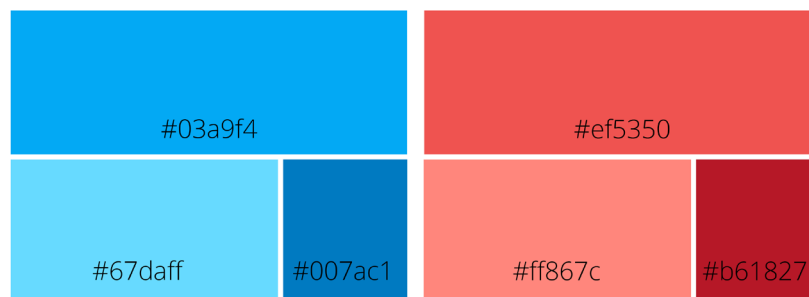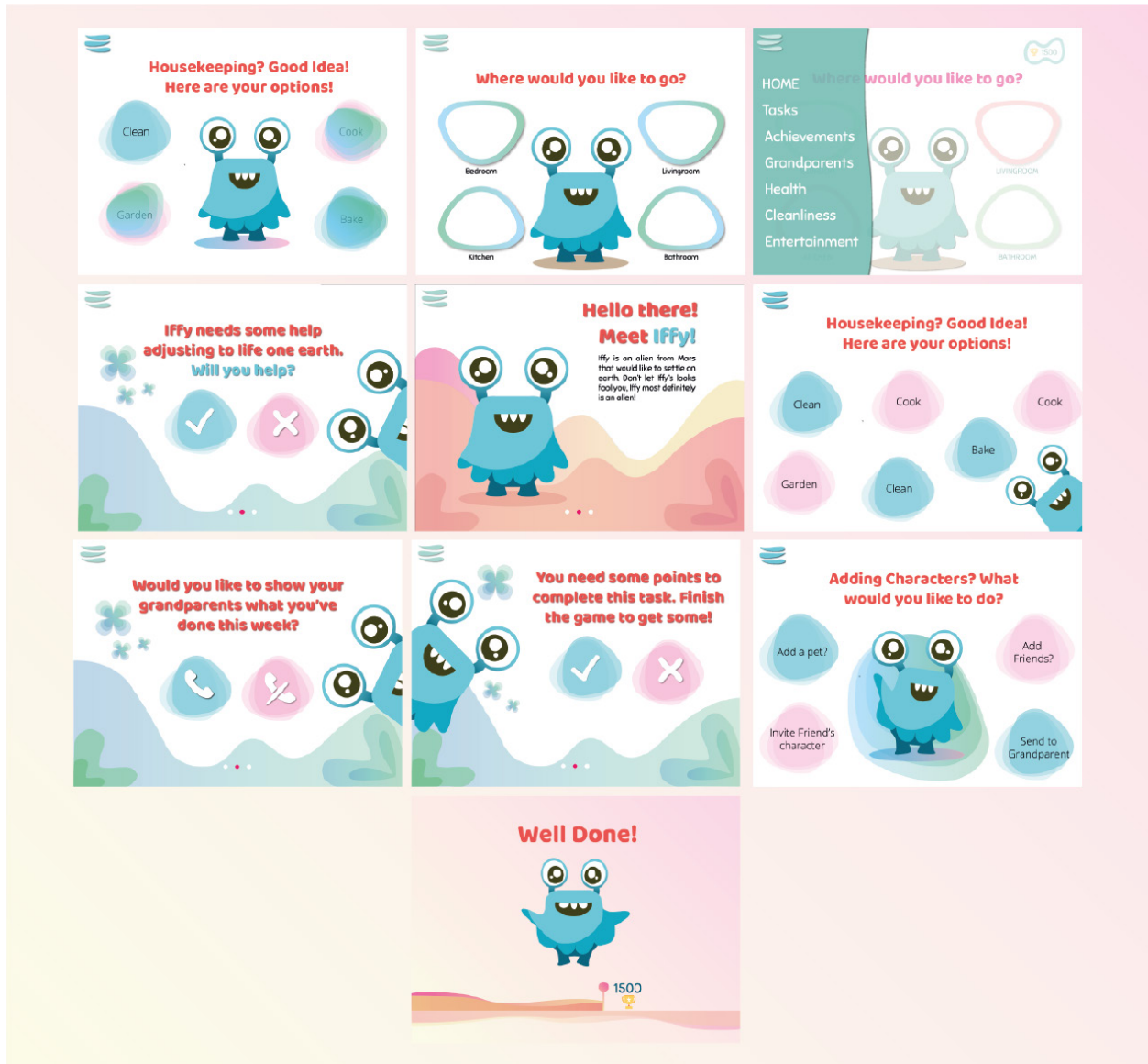|	
#03a9f4	#ef5350
#67daff / #007ac1	#ff867c / #b61827

Figure 6.7: Color Scheme and fonts used

Figure 6.8: Final screens of mobile application

Figure 6.9: Digital render of screen on an iPad

6.4 Exhibition at Krannert Art Mueseum

Figure 6.10: Exhibition at Krannert Art Museum

The project was exhibited at Krannert Art Mueseum in Champaign. A micro projector with a looping video was used to emulate the actual service as the development of software to create the actual product was beyond the scope of this project. (Figure 6.10)

CHAPTER 7: CONCLUSION

The "home" is traditionally defined as the place where one lives permanently. However, it can also be defined as the social unit formed by a family or household living together. It is this aspect of family and living that this work focuses on. With an aging population, it is essential to form bridges that allow older adults to share skills and knowledge with the next generation. Without these bridges, we risk the irreversible loss of a treasure trove worth of human capital and expertise.

Changes in technology and the manner in which people live has led to a multitude of changes in the way society operates and is structured. However, it is crucial to ensure that these changes do not alienate older adults. This project leverages the potential of technology to bring people closer together with a focus on bringing grandparents and grandchildren together. It is anticipated that this project will allow for richer communication between generations and across distances ensuring that skills, knowledge, and stories of older generations are not lost to society. With the advent of social media and new communication methods, there's been a paradigm shift in how people interact with one another. As such, it is important to remember the real and tangible ties that bring families together and make for a healthy upbringing.

While the project dealt with the problem area with a well-defined scope, there is potential for future work. This project dealt with projection mapping and mixed reality within the confines of a physical object, however, much can still be explored in terms

of the possibility of expanding the system beyond the limitations of the object, per se. The entire home itself can be considered a playground, offering almost limitless possibilities in terms of storytelling and imagination. The use of projectors and projection mapping software allows for the platform to extend beyond small physical objects, a potential that can be exploited to enhance the experience of both the grandparents and grandchildren. Another area that needs further exploration of the role of grandparent-parent interaction along with further work on defining both the physical and digital experience for grandparents.

In conclusion, while the project deals with the problem area in its own way, the space still requires a tremendous amount of work to ensure that older adults reap the benefits of technological change and to minimise the detrimental effects of said change. There is a need to expand the definition of "home" beyond the confines of just the physical location of the house to allow for the inclusion of family, no matter how much distance or age separates the individual members from each other.

REFERENCES

Beutel, Manfred E., et al. "Loneliness in the General Population: Prevalence,

    Determinants and Relations to Mental Health." BMC Psychiatry, vol. 17, Mar.

    2017. PubMed Central, doi:10.1186/s12888-017-1262-x.

Bitsko, Rebecca H., et al. "Epidemiology and Impact of Health Care Provider–

    Diagnosed Anxiety and Depression Among US Children." Journal of

    Developmental & Behavioral Pediatrics, vol. 39, no. 5, June 2018, p. 395.

    journals.lww.com, doi:10.1097/DBP.0000000000000571.

Boyd, Danah M., and Nicole B. Ellison. "Social Network Sites: Definition, History, and

    Scholarship." Journal of Computer-Mediated Communication, vol. 13, no. 1, Oct.

    2007, pp. 210–30. academic-oup-com.proxy2.library.illinois.edu, doi:10.1111/

    j.1083-6101.2007.00393.x.

Bureau, US Census. 2017 National Population Projections Tables. https://www.census.

    gov/data/tables/2017/demo/popproj/2017-summary-tables.html. Accessed 5 July

    2019.

---. "Older People Projected to Outnumber Children." The United States Census Bureau,

    https://www.census.gov/newsroom/press-releases/2018/cb18-41-population-

    projections.html. Accessed 30 June 2019.

CDC. "Developmental Milestones." Centers for Disease Control and Prevention, 24

    Sept. 2018, https://www.cdc.gov/ncbddd/actearly/milestones/index.html.

"Developing Websites for Older People: How Web Content Accessibility Guidelines

(WCAG) 2.0 Applies." Web Accessibility Initiative (WAI), 3 July 2019, https://www.
w3.org/WAI/older-users/developing/.

Ghandour, Reem M., et al. "Prevalence and Treatment of Depression, Anxiety, and
Conduct Problems in US Children." The Journal of Pediatrics, vol. 206, Mar.
2019, pp. 256-267.e3. www.jpeds.com, doi:10.1016/j.jpeds.2018.09.021.

Grandparent Talk Continuum Games. https://continuumgames.com/shop/grandparent-
talk/. Accessed 28 June 2019.

Ijsselsteijn, Wijnand, et al. "Digital Game Design for Elderly Users." Proceedings of the
2007 Conference on Future Play - Future Play '07, ACM Press, 2007, p. 17. DOI.
org (Crossref), doi:10.1145/1328202.1328206.

"Journey Mapping 101." Nielsen Norman Group, https://www.nngroup.com/articles/
journey-mapping-101/. Accessed 1 July 2019.

Luanaigh, Conor Ó., and Brian A. Lawlor. "Loneliness and the Health of Older People."
International Journal of Geriatric Psychiatry, vol. 23, no. 12, Dec. 2008, pp. 1213–
21. DOI.org (Crossref), doi:10.1002/gps.2054.

Mather, Mark. Fact Sheet: Aging in the United States – Population Reference Bureau.
https://www.prb.org/aging-unitedstates-fact-sheet/. Accessed 5 July 2019.

Moment Garden. https://momentgarden.com/. Accessed 28 June 2019.

Oliemat, Enass, et al. "The Use of Touch-Screen Tablets in Early Childhood: Children's
Knowledge, Skills, and Attitudes towards Tablet Technology." Children and Youth
Services Review, vol. 88, May 2018, pp. 591–97. ScienceDirect, doi:10.1016/j.
childyouth.2018.03.028.

Ortman, Jennifer, et al. An Aging Nation: The Older Population in the United States. May

2014, p. 28.

Parten, M. B. "Social Participation among Pre-School Children." The Journal of

Abnormal and Social Psychology, vol. 27, no. 3, 1932, pp. 243–69. DOI.org

(Crossref), doi:10.1037/h0074524.

Robinson, Thomas N., et al. "Screen Media Exposure and Obesity in Children and

Adolescents." Pediatrics, vol. 140, no. Suppl 2, Nov. 2017, pp. S97–101. PubMed

Central, doi:10.1542/peds.2016-1758K.

Skype | Communication Tool for Free Calls and Chat. https://www.skype.com/en//.

Accessed 28 June 2019.

"Usability 101: Introduction to Usability." Nielsen Norman Group, https://www.nngroup.

com/articles/usability-101-introduction-to-usability/. Accessed 29 June 2019.

Vanoverbeke, Christina. "Write Stuff: Letter Kit Lets Grandparents Connect with

Grandkids." Tribune, The (Mesa, AZ), Mar. 2006. EBSCOhost, http://www.library.

illinois.edu/proxy/go.php?url=http://search.ebscohost.com/login.aspx?direct=true

&db=nfh&AN=2W62W63652032141&site=eds-live&scope=site.

Victor, Christina R., and Keming Yang. "The Prevalence of Loneliness Among Adults: A

Case Study of the United Kingdom." The Journal of Psychology, vol. 146, no. 1–2,

Jan. 2012, pp. 85–104. Taylor and Francis+NEJM, doi:10.1080/00223980.2011.6

13875.

Web Accessibility for Older Users: A Literature Review. https://www.w3.org/TR/wai-age-

literature/#who-a. Accessed 30 June 2019.

Williams, Hannah. "Persona Mapping : Why Use and How to Create Buyer Personas."

    United Kingdom — Meltwater, 12 May 2017, https://www.meltwater.com/uk/blog/

    persona-mapping/.