Title

Playful Health Technology: A Participatory, Research through Design Approach to Applications for Wellness

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Playful Health Technology: A Participatory, Research through Design Approach to Applications for Wellness

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by

Jared S. Duval

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The Dissertation of Jared S. Duval is approved:

Professor Sri Kurniawan, Chair

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Vice Provost and Dean of Graduate Studies

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UNIVERSITY OF CALIFORNIA
SANTA CRUZ

Abstract

Katherine Isbister
Sri Kurniawan
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COMPUTATIONAL MEDIA

Playful Health Technology: A Participatory, Research through Design Approach to Applications for Wellness

by Jared S. Duval

Games and play have the potential to offer people with disabilities a cost-effective, personalized, data-driven, connected, and motivating context for otherwise tedious and repetitive wellness routines. The paramount challenge in creating playful health structures and games is creating a motivating experience with mechanics that translate into improved health outcomes—a wicked problem. To this end, I use Research through Design to explore multiple approaches to the co-creation of games and play with various populations, including children with speech impairments, adults with developmental disabilities, stroke survivors, and children with Sensory-Based Motor Disorder. I have initiated and developed three health applications, which serve as case studies where I explore identifying best practices, unique insights, and suggestions for future creators. Specifically, I discuss game-first versus therapy-first approaches and closed-game systems versus more open-ended playful systems. Through this work, I have co-created two design methods for creating playful technology drawing inspiration from social media and from content creators with disabilities. The first, Situated Play Design, is a novel approach to uncovering contextual manifestations of play as design material for everyday technology. The second, DREEM (Disability-Related Empathy from Existing Media) leverages the rich cultural labor from content creators with

disabilities as an entry point for developing an authentic, empathy-based assistive technology research agenda. For both of these design methods, I have employed a series of design strategies resulting in the co-creation of speculative design catalogs that serve as case studies to exemplify the value of these methods.

The contributions of this dissertation are two-fold. The first dimension is applied: I build well-informed systems that provide a motivating context for various forms of therapy for multiple populations of people with disabilities. The second dimension is methodological: I propose Situated Play Design and DREEM as novel approaches to creating playful technology rooted in perspectives of disability social justice. Overall, my work hopes to inspire, provoke, and empower designers to co-create innovative technology that improves the condition of some of today's toughest Wicked Problems through play and disability advocacy.

Dedicated to my parents, Lisa and Rich Duval...

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1. Jared Duval. 2017. A mobile game system for improving the speech therapy experience. In Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services, ACM, New York, NY, USA, 3.

2. Jared Duval. 2020. Approaches for creating therapy games. SIGACCESS Access. Comput. 2, 126 (March 2020), 1–1.

3. Jared Duval, Ferran Altarriba Bertran, Siying Chen, Melissa Chu, Divya Subramonian, Austin Wang, Geoffrey Xiang, Sri Kurniawan, and Katherine Isbister. 2021. Chasing play on TikTok from populations with disabilities to inspire playful and inclusive technology design. In Proceedings of the 2021 Conference on conference on human factors in computing systems (CHI '21), may 8–13, ACM, Online (originally Yokohama, Japan), 15.

4. Jared Duval, Zachary Rubin, Elizabeth Goldman, Nick Antrilli, Yu Zhang, Su-Hua Wang, and Sri Kurniawan. 2017. Designing Towards Maximum Motivation and Engagement in an Interactive Speech Therapy Game. In Proceedings of the 2017 Conference on Interaction Design and Children, ACM, Stanford California USA, 589–594.

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11. Ferran Altarriba Bertran, Jared Duval, Katherine Isbister, Danielle Wilde, Elena Márquez Segura, Oscar Garcia Pañella, and Laia Badal León. 2019. Chasing Play Potentials in Food Culture to Inspire Technology Design. In Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts (CHI PLAY '19 Extended Abstracts), Association for Computing Machinery, New York, NY, USA, 829–834.

12. Ferran Altarriba Bertran, Jared Duval, Elena Márquez Segura, Laia Turmo Vidal, Yoram Chisik, Marina Juanet Casulleras, Oscar Garcia Pañella, Katherine Isbister, and Danielle Wilde. 2020. Chasing play potentials in food culture: Learning from traditions to inspire future human-food interaction design. In Proceedings of the 2020 ACM designing interactive systems conference, 979–991.

13. Ferran Altarriba Bertran, Elena Márquez Segura, Jared Duval, and Katherine Isbister. 2019. Chasing Play Potentials: Towards an Increasingly Situated and Emergent Approach to Everyday Play Design. In Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19), Association for Computing Machinery, New York, NY, USA, 1265–1277.

14. Ferran Altarriba Bertran, Elena Márquez Segura, Jared Duval, and Katherine Isbister. 2019. Designing for Play That Permeates Everyday Life: Towards New Methods for Situated Play Design. In Proceedings of the Halfway to the Future Symposium 2019 (HTTF 2019), Association for Computing Machinery, New York, NY, USA, 4.

15. Ferran Altarriba Bertran, Elena Márquez Segura, Jared Duval, and Katherine Isbister. Submitted. From Game Design Experts to Play Chasers: Towards an Increasingly Situated Approach to Play Design. In Submitted to the Conference on Human Factors in Computing Systems (CHI'19).

Chapter 1

Introduction

1.1 Introduction

In this dissertation, I present my Research through Design[2] (RtD)-informed doctoral work exploring how to co-design playful and gameful technology that makes the healing process more meaningful and effective. My research responds to the need for more equitable healthcare solutions and design methods that support their creation[3]. This dissertation aligns with a vast body of work that foregrounds the importance of co-designing [4] playful technologies [5] in the domain of health and rehabilitation [6].

To facilitate a move toward technology as a tool for achieving health that is more socio-emotionally sensitive and democratic, I present a two-fold contribution. The first dimension is applied: I present 3 case studies where I co-created health applications for various populations of people with disabilities[1]. The co-design of these case studies demonstrates novel insights and knowledge about how technology can support the specific needs of these populations. My second contribution

[1] Person-first disability language (e.g., person with disabilities) and identity-first language (e.g., disabled person) are used interchangeably throughout this dissertation, as is the custom in the communities I worked with.

is methodological: I propose 2 novel design methods for designing playful technology rooted in disability justice. The first method, "Situated Play Design," is a bottom-up approach for leveraging contextual manifestations of play as design material for everyday technology. The second method, DREEM (Disability-Related Empathy from Existing Media), borrows from the humanities and social sciences to enable scholars in the assistive technology field to develop research agendas that are authentic and sensitive to the needs of disabled populations, while also emphasizing respect for the previous cultural labor of disabled populations and their time. These methods are important because a recent survey of ASSETS and CHI accessibility work showed that only 16 methodological contributions (3.2% of all) have been made to the accessibility community since 1994 [3].

Overall, my research is grounded in Human-Computer Interaction (HCI) and explores the intersection of social computing, health, and play. To better understand the complex, intersecting dynamics at the heart of disability, technology, and healthcare, I employ Research through Design and co-create systems in collaboration with disabled populations. The first case study—and my primary doctoral research project—is SpokeIt, a speech therapy game for children born with a cleft lip or palate. The second case study, Spellcasters, is a multiplayer virtual reality game that was originally developed purely for entertainment and subsequently evolved into a stroke rehabilitation game. The final case study presented here is Cirkus, a playful wearable probe that supports many exercise-promoting games in children with Sensory Based Motor Disorder. Through these case studies, I have explored various technology design approaches, including a therapy-first approach, a game-first approach, using varying levels of structure in play and flexibility, participatory machine learning, and participation from diverse stakeholders. The experiential nature of this work enabled me to co-found Situated Play Design and DREEM—methods to better support creators who are interested in creating technology that supports play for people with disabilities. To illustrate the utility of these methods, this dissertation includes design ventures in the domains of food traditions, urban spaces, and social media that resulted in design catalogs of speculative futures. I hope this work serves as a seed for an exciting research program that explores how to engage diverse stakeholders in co-designing technology futures that realize play's potential in serving the needs of disabled people.

In this chapter, I begin by characterizing the motivations of my work, framing it as a wicked problem (Section 1.2). Given the nature of wicked problems, this research can never be completed without a defined scope, so in Section 1.3, I discuss my doctoral focus and the limitations of my methodology, resources, and generalizability of findings. Next, I provide an overview of the dissertation contents (Section 1.4). Overall, I hope that this chapter helps position the outcomes of my doctoral research for the reader.

1.2 Motivations

A wicked problem is a social or cultural problem that is difficult or impossible to solve for as many as four reasons: incomplete or contradictory knowledge, the number of people and opinions involved, the large economic burden, and the interconnected nature of these problems with other problems [7]. There are 10 characteristics of wicked problems:

1. Wicked problems have no definitive formulation
2. It's hard, and may be impossible, to measure or claim success with wicked problems because they bleed into one another

3. Solutions to wicked problems can be only good or bad, not true or false. There is no idealized end state to arrive at, and so approaches to wicked problems should be tractable ways to improve a situation

4. There is no template to follow when tackling a wicked problem, although history may provide a guide.

5. There is always more than one explanation for a wicked problem

6. Every wicked problem is a symptom of another problem

7. No mitigation strategy for a wicked problem has a definitive scientific test because humans invented wicked problems and science exists to understand natural phenomena

8. Offering a ”solution" to a wicked problem frequently is a ”one shot" design effort because a significant intervention changes the design space enough to minimize the ability for trial and error

9. Every wicked problem is unique

10. Designers attempting to address a wicked problem must be fully responsible for their actions

Examples of wicked problems include poverty, homelessness, food scarcity, malnutrition, and crime. Inequalities in healthcare is the wicked problem that drives my research. My research is particularly geared toward addressing the inequalities faced by those from lower socioeconomic statuses and those who experience barriers to the services they need. Much of the inequalities in the United States healthcare system are due to barriers related to costs and gaps in health insurance coverage. In 2020, 8.6% of people (28 million) in the United States did not have health insurance at any point during the year [8]. Citizens paid 375.6 billion dollars out of pocket for their healthcare in 2019[9]—none of these expenditures

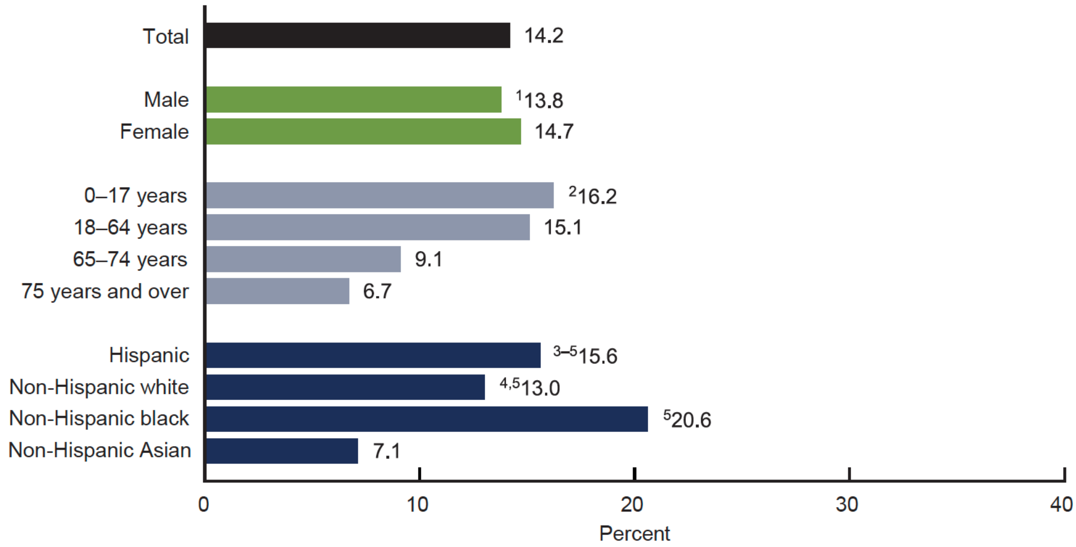


FIGURE 1.1: Percentage of persons who were in families having problems paying medical bills in the past 12 months, by sex, age group, and race and ethnicity: United States, 2018 [1]

includes costs covered by health insurance. It is no surprise that many Americans are struggling to afford their healthcare needs—and that those struggling are disproportionately Hispanic, Black, and female [1]. These inequalities can be seen in Figure 1.1 previously published by Cha and Cohen. One may assume that older adults would have more difficulty paying their medical bills due to their higher prevalence of medical needs, but in reality, younger Americans and children struggle more due to disparities in generational wealth. Designing low-cost applications that use ubiquitous sensors found in our everyday technology represents a fertile ground for disrupting egregious healthcare costs by providing accessible solutions remotely and at scale.

Beyond access and cost barriers, this wicked problem is exacerbated by an ableist system that shapes how and what we design [10]. A handicap is not a person's disability. Rather, it is the sum total of barriers that society and technology place on people with disabilities [11]. My research and health applications are not intended to 'fix' disabled people because they are not broken—my research aims to complement the lived experience of disability. Within this dissertation, there are no statistics or models that claim to solve problems for, or generalize, entire populations. Instead, there are co-designed artifacts and experiences that explore health and healing. In lieu of using quantitative measures that assume one body and have the potential to exacerbate existing inequalities [12], this work attempts to contribute knowledge through built relationships and forged alliances that leverage data in participatory collaborations. Wicked problems are invented by humans — they are not natural phenomena - so there is no definitive scientific test I can employ [13]. My research attempts to move against the traditional medical model that results in technoableism [10] by supporting a more holistic model of health that recognizes the interdependent social relationships we all rely on [14].

As technology becomes increasingly present in our lives and daily routines, it is important to consider the role of computation. Our rich socio-emotional needs often come second to utilitarian productivity goals embedded in our designs [15]. Much of my research is concerned with play and the vital role it has in leading a wholesome life [16]. Play is a vital part of all human life because we are creatures motivated by pleasure, socio-emotional connection, agency, and positive feelings [5]. Play is valuable for its own sake [5, 16], but in this dissertation, I set out to position play as an integral aspect of health and wellness that should be intentionally designed for and within health products. I argue that play embodies the qualities needed to tackle this wicked problem [13].

Herein are projects that support a myriad of populations including older adults, children, people with physical impairments, people with intellectual disabilities, and people with invisible disabilities. Many of the individuals I collaborated with had co-occurring disabilities and inter-sectional identities. Experiencing disability is incredibly personal but it is not individual—we must look at the structures and context in which people are valued or not valued including the social, environmental, and designed world [10]. My research is not interested in a particular community or diagnosis—instead it aims to better understand how we might design technology that includes disabled voices and perspectives.

In this section, I presented many higher-level goals and meta-reflections on the field that will take years of collaborations to disrupt. Of course, this dissertation cannot aim to fully address each of these motivations. The work presented herein touches on each of these aspects and has enabled me to better articulate an exciting research program that I plan to conduct for years to come. In the following section, I clarify the work that I have done to date towards these higher level motivations, while remaining transparent about the obvious shortcomings of this work, with regard to resources, time, generalizability, and methodology.

1.3 Scope

My research cannot solve this wicked problem. My doctoral research has elucidated more questions than answers. The motivations discussed above will take many lifetimes and bodies to make sense of. There is no easy one-size-fits-all solution for this work—there is only more work to be done, more voices, more data, more iterations, more critiques, more justice, more resistance, and more growth.

Zimmerman argues that reframing is an important component of a RtD contribution and cites my work [17] as a case of effectively employing RtD reframing for developing new research [18]. My doctoral research has been just that—a journey of reframing how one might go about designing technology that supports people with disabilities. As the case studies unfold in the coming chapters, using the medical model as an entry point into designing these applications gives way to social models. Structured games yield to flexible play structures. Machine learning becomes the antagonist rather than the facilitator. The paradigm shifts, methods inspired from these reflections, and lessons learned through interactions with disabled communities are highlights of this dissertation journey.

Perhaps the greatest limitation of my work is that the case studies are unfinished. They are applications designed to impact society, but because they have not been released, there are no in-the-wild studies, no controls, no longitudinal assessments, and no broader impact—at least, not yet. As a designer, I am responsible for these designs [7] and I will devote the rest of my career to ensuring their efficacy. My doctoral research is not about each case study's measured in-the-wild impacts. Rather, it is about the process of thoughtfully building these systems and using speculative methods to mitigate risks from these applications [19]. However, qualitative and quantitative measures are not absent from this dissertation—they are used at pivotal points and during co-design sessions to validate intents and progress.

The second greatest limitation of the work to follow is the generalizability of my findings. The individual groups of people with disabilities I collaborated with do not represent the entire population of disabled people—and the very notion of grouping all these people together is constructed through an ableist society [10]. When I began this work, I struggled with knowing where to begin, how to adapt methods to be accessible, and with my own identity within this field. The accounts of work in this thesis represent strides towards inclusive design methods, discourse on technology that serves disabled populations, and a journey that may help inform future creators.

The work I present in this dissertation aligns with, and extends bodies of work that employ playful interventions to promote health and well-being [6]. Considering the pervasive role of computation in our lives and disability justice, I see a need to further explore how we can reclaim healthcare to serve our social and emotional needs—and place them at the forefront of technology design. In the next subsection, I unpack how my doctoral research contributes to advancing that agenda.

1.4 Summary of Contents

In this section, I provide an overview of the contents of this dissertation. Overall, I hope this chapter helps orient the reader through the various projects I have collaborated on that make up the contributions of my doctoral research. Each of these projects are collaborations—from this line on, when I say "I", I mean "we". In each chapter that describes a specific research project, I include a section titled "My Role" that describes my individual contributions to the work with credit to my collaborators.

1.4.1 Background

I am particularly captivated by play and the potential for it to move us forward. Play affords a unique opportunity for studying how various populations appropriate tools and technology to serve their needs. I believe play contains qualities that are naturally healing and is a great vehicle for addressing society's wicked problems because it enables us to explore outside current norms and barriers. Play is naturally iterative with ever-changing rules and possibilities—it provides an effective approach to conducting RtD.

In Chapter 2, I begin by arguing for why play is an apt vehicle to maintain or improve one's health. I describe previous research on play and synthesize how play is an important component to the human experience. I think of play as a spectrum that naturally leads into games as more structure and rules are added. Serious Games for Health live within the more structured realm of games. In this chapter, I coin a new term, Serious Play for Health, that helps me articulate how many of my research projects live more on the play side of the spectrum than traditional Serious Games for Health. I provide related work that has used play for healing—namely play therapy. I discuss social play because I believe healing is seldom done alone. All of my projects are systems-based, so I present a review of computation as it relates to my work and the ethics involved with systematizing social play for healing.

1.4.2 Research Questions and Methods

In this introductory chapter, I began framing my work as a wicked problem and introduced my overarching RtD approach. In Chapter 3, I employ the positioning I established in Chapter 2 to articulate the broader research questions that drive my work, which revolves around how we approach the design of playful systems for health. Finally, I provide a meta-level overview of the methodologies I am inspired by, including RtD and Participatory Design. I do not get into specific methodological details in this chapter because each of my case studies and projects employ their own set of methods that are defined in their respective chapters. The following three chapters are the case studies I worked on.

1.4.3 SpokeIt

SpokeIt is a mobile speech therapy game for children born with orofacial cleft. SpokeIt's gameplay is entirely driven by speech via two independent speech recognition systems that are capable of distinguishing correct speech from common speech errors [20]. As my primary project, SpokeIt has gone through many iterations, but the limitations of speech error sensing has always been a concern. While speech error sensing has greatly improved, resulting in a highly polished experience, these concerns led to the development of SpokeIt, which involved moving

FIGURE 1.2: Screenshots of SpokeIt

from a closed Serious Game for Health to the more flexible realm of Serious Play for Health. SpokeIt was co-designed with medical professionals, developmental psychologists, children with cleft speech, and adults with developmental disabilities co-occurring with speech impairments [20] using Participatory Design [21, 22], Wizard of Oz [23], tangible design probes [24, 25], and rapid medium-fidelity prototyping [24].

1.4.4 Spell Casters

Spell Casters, shown in Figure 1.3, is a social virtual reality (VR) game previously developed purely for entertainment, where teams of 5 wizards battle in a magical duel by drawing gestures with their "wands" (VR controller) to cast spells. Before the duel, players select a wizard hat with a color that corresponds to the role (attacker, tank, or support) and the set of available spells. Each team receives a pool

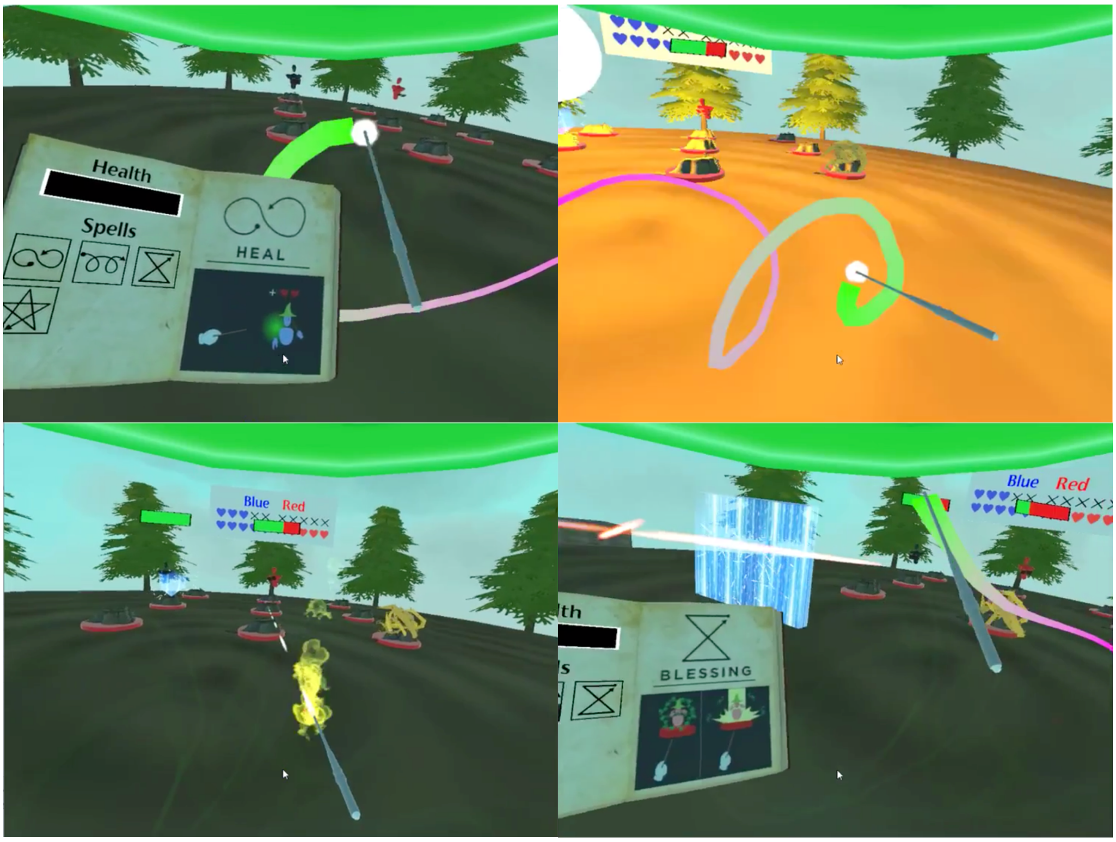


FIGURE 1.3: In-Game capture of Spell Casters

of "lives" and the last team standing wins. By outfitting the "wand" in a Stroke Survivor's weaker hand and changing the spell gestures to exercises that are beneficial to rehabilitation, Spell Casters has the potential to demonstrate how games developed primarily for entertainment can be adapted for therapy purposes, reducing development time and costs with designs that have already proven to be fun. To be appropriate for stroke rehabilitation, a number of changes were necessary: accessibility features were added, the gestures system was redeveloped so that individual exercises could be custom made for each individual stroke survivor's needs, and support was added for clinician practices. Specifically, we created a "training ground" for medical professionals to train the gesture recognition system and developed a companion app that serves as a dashboard for medical professionals to review progress and customize new in-game goals.

1.4.5 Cirkus

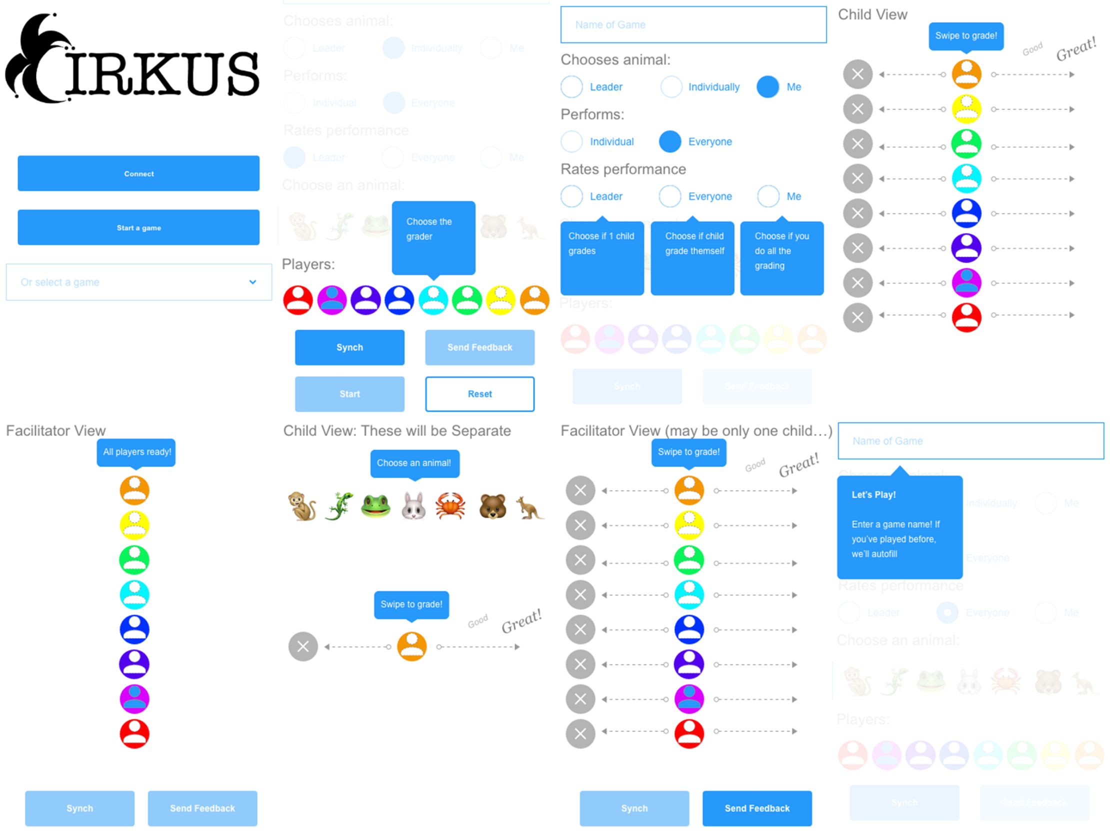


FIGURE 1.4: Screenshots of Cirkus Wire frame

Cirkus (Wireframe shown in Figure 1.4) is a Serious Play for Health system for children with Sensory-Based Motor Disorder (SBMD). The system resulted from a collaboration with Upsala University's Super Trouper project and began with the development of 6 wearable training devices called Physical Training Technology Probes (TTPs) that can sense and support SBMD therapies, including precise motor skills, gross movements, overall coordination, breathing, muscle strength, focus, balance, and posture [26]. The TTPs were proven effective with trainers during authentic circus-themed training situations. Super Trouper heavily relies on circus classes facilitated by circus performers who are familiar with SBMD and the TTPs. The goal of my work was to develop a Serious Play for Health system that will work in more contexts, such as home. Therefore, I designed a system that is able to classify animal exercises (e.g. jumping like a frog, crawling like a lizard) given motion data. We took a participatory training approach for the machine learning where children with SBMD co-designed games supported by the Cirkus app while wearing smart devices with movement sensors. The design offers many games and supports self-grading, peer-grading, facilitator-grading, any movement within a timed window, automatic logging, and all three types of social play outlined in the Background chapter.

1.4.6 Situated Play Design

In each of the three case studies described above, play is an integral element of the experience, but designing for play is difficult due to its elusive and contextual nature [5]. My collaborators and I became fascinated with the idea of conducting design work where play is the goal. Through this collaboration, Situated Play Design [5] was born. In Chapter 7, I share some details about this method that I co-founded as well as case studies that I participated in that illustrate the method's utility and effectiveness. Specifically, I share details on a workshop in Barcelona that I co-organized. The workshop featured a collection of food traditions from numerous cultures as material for inspiring playful Human Food Interactions [27] and research that I co-lead on re-imagining urban spaces for play. Situated Play Design is a novel method that can be used to design any technology that has play as its primary focus. Using Situated Play Design as a research model, I became interested in creating a spin-off method that is particularly suited to support people with disabilities: DREEM.

1.4.7 DREEM

Within the assistive technology research community, there have been growing concerns and critiques around technosolutionism, lack of social justice, and missing lenses of critical disability studies. Inspired to do and be better, my collaborators and I set out to create actionable and procedural innovation inspired by these discussions. Using the Situated Play Design research program as a model, we began a RtD process and literature review revolving around these issues and found that many of these problems stem from a lack of appropriate empathy. Empathy has long been considered an important component of design and design research. We developed DREEM (Disability-Related Empathy from Existing Media), a concept characterized by the immersion of the designer in the content created by disabled individuals as a precursor to participatory work, so that appropriate empathy is developed as a basis for productive future interactions with communities of disabled people. I co-lead a research program that oversaw young scholars who are new to the assistive technology field and who employed DREEM and completed case studies using this emerging method. The development of DREEM and these case studies are presented in Chapter 8.

1.4.8 Chasing Play and DREEMing on TikTok

Excited by both DREEM's and Situated Play Design's potential and motivated to illustrate their power, I conducted a summer research program with 6 high school students who employed these methods on TikTok. The results of this intense 8-week program were published in the Computer Human Interaction (CHI) conference [17]. Included in Chapter 9 are the motivations for designing playful technology inspired by content created by people with disabilities (the content does not necessarily have a productive or utilitarian agenda), a thematic analysis of the content scraped by the high school students on the platform, a speculative design catalog created by the high school students, and a discussion on the implications of this work. The purpose of this chapter is to convince the reader that the co-founded methods that resulted from working on my case studies are valuable and that they have the potential to help future scholars entering the field of assistive technology.

1.4.9 Reflection

There is an obvious breadth to the work presented in this dissertation. From Serious Play for Health systems to design methods to food to urban spaces, this chapter is intended to provide some insights that tie all of the foregoing research together. While there is much breadth to the projects presented in this dissertation, there is also a unifying theme of designing for play and health. My RtD-led doctoral work did not solve any wicked problem, but it does provide insights into the approach of designing technology aimed to help people with disabilities. I have explored play-first approaches, therapy-first approaches, machine learning's role in these technologies, and novel design methods for creating playful health systems. In Chapter 10, I aim to share some of these insights and discuss an exciting future research program that will drive my career, enabled by this doctoral adventure.

Chapter 2

Background

2.1 Introduction

There are many qualities of play worth exploring in the context of health: solo play, social play, competitive play, collaborative play, technology-mediated play, and people-mediated play, to name a few. All of these qualities can be categorized into three overall themes: play, social relationships, and technology. I will discuss these three themes in this chapter because each are paramount in informing the creation of Serious Play for Health systems. However, there are two sides to every coin, and each of the three themes has important considerations. In the "Ethical Considerations" section of this chapter, I discuss these for each of the three themes.

2.2 Theme 1: Play

2.2.1 Play is a Natural Vehicle for Healing

"Health as the totality of a person's existence recognizes the interrelatedness of the physical, psychological, emotional, social, spiritual, and environmental factors that contribute to the overall quality of a person's life" [28]. Health is a state as observed at one point in time. Healing is a *process* of working towards improved health. Healing is intentional—it requires skill-building, enlisting help, focusing on solutions, trying new approaches, self-evaluation, and practice [29]. Play is an apt vehicle to bring about healing because it embodies the very qualities of the intentional healing process: it is biologically engineered to help us learn and build skills [30], it is naturally social [15, p. 9-10], and the voluntary nature of play allows us to focus on the style of play over the outcome [31]. Play captivates us all: scientists, researchers, parents, children, teachers, and adults alike. Like eating, sleeping, dying, and breathing, play is something we all do. It can be thought of as a biological trait [30], an attitude [32], a phenomenological state [33], a set of properties [30], a state of mind free from time [34], a process [35], or an educational tool [36]. Many great minds have tried to define play, find its origin, and understand its purpose. For this work, the idea of understanding play in its totality is less important than understanding how varying types of play might bring about healing (though play has probably been healing us since before we invented language—or before we walked on land).

Figure 2.1 probably does a much better job of visually defining play than I could ever write—and I will not attempt to formulate my own definition. Instead, I will synthesize others' definitions and how they relate to the healing process. Figure 2.1 provides a nice definition of play for many reasons. Play exists in all animals including mammals, reptiles, birds, sea creatures, and probably insects [37] (I've watched bees twerk as they return to their hive after collecting honey and no amount of scientific explanation of "releasing a scent through their Nasonov Gland" will convince me that it is not a mini dance party). Play permeates through the species barrier, such as a dog playing *tug-of-war* with a tiny human. It can change rapidly. That game of *tug-of-war* may quickly become *fetch* and then *keep-away* followed by the *zoomies*, and finally, lots of belly rubs—all play. In

FIGURE 2.1: A visual definition of play: A boy and dog playing *tug-of-war*

Figure 2.1, play is healing the pup—it is providing the dog purpose and exercise, preventing depression and obesity. It is healing the human for the same reasons. The relationship is symbiotic and mutually beneficial biologically for both their physical and mental well-being. This is the rationale for having service dogs and emotional support animals. Play is a natural vehicle for healing. The play between this dog and child would fall under "Unfocused Healing" in Figure 2.2.

Stuart Brown hates to define play (as it takes the joy out of it), but nonetheless describes seven properties of play [30, p. 15-18]:

1. It is apparently purposeless and done for its own sake
2. It provides a continuation desire
3. It is voluntary
4. It has inherent attraction
5. It provides freedom from time

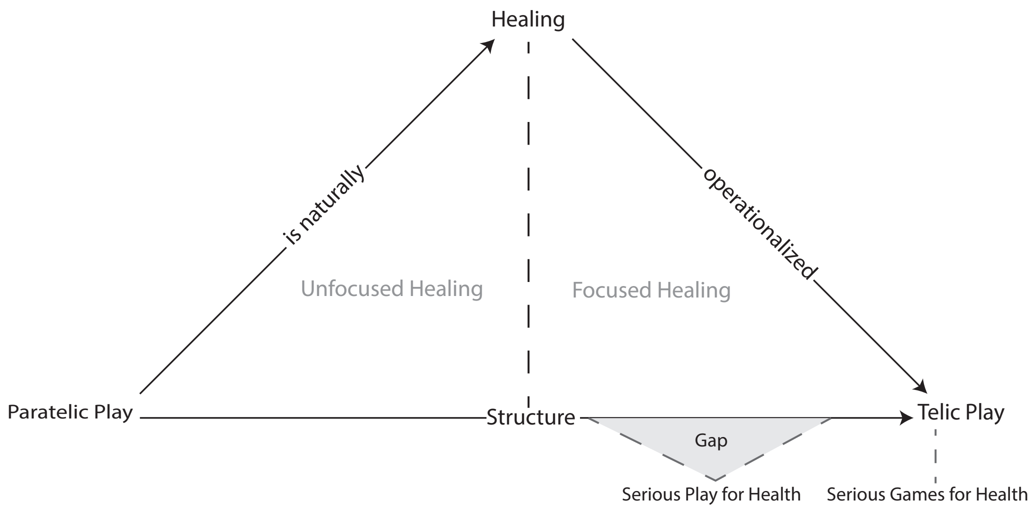


FIGURE 2.2: Play is naturally healing, but to focus that healing, play must be operationalized and structured. Serious Games for Health are generally closed systems with rigid rules. Serious Play for Health is structured play aimed to improve a specific health outcome, but is left more open and ambiguous for flexibility to be appropriated in different contexts and by different stakeholders

6. It diminishes our consciousness of self

7. It has improvisational potential

Each of these properties is beneficial for healing:

Even **purposeless play (1)**—or paratelic play—is useful for healing because it provides an opportunity for breaks, which are a necessary component of serious activities like healing and work [38]. When we engage in activities, what we often remember is not the activity itself, but the spontaneous moments that arise from the activity. For example, I remember less about what was practiced in theater rehearsal than I do about the forty of us storming Denny's at 1am for appetizers and dessert afterwards. I remember less about running laps during soccer practice than I do about eating orange slices with the team. Group cohesion and fun motivated me to attend practice and rehearsal. The activity itself (soccer or theater) made me a healthier person and placed me in a phenomenological state [33]. I learned delayed gratification, how to navigate social structures, and work ethic. I improved my stamina, dexterity, and emotional intelligence. Play can elicit a sense of pronoia, or the suspicion that the universe is conspiring on your behalf to help you [39]. Play **provides a continuation desire (2)** and inspired me to keep participating in activities that made me a healthier person. “Strength—strength of mind and of body—flows from understanding. Play trains our physical skills, sharpens our mental abilities, and deepens our insights into our social capabilities" [35]. Play heals everyone.

Play is voluntary (3) [30, p. 17] and this is a characteristic that goes hand-in-hand with healing because healing is intentional [29]. When we play, we want to keep playing. When play is over, we often want to play again. When play is not working, we tweak it to keep it alive. When we reach a new milestone in healing, we often want to keep healing. When we overcome a healing barrier, we often want to tackle the next one. We choose to stop healing when we feel like it is no longer working, but like play, when when we fail, we should try new things, new forms of therapy, new tactics to keep it alive. Like play, participating in the healing process is an active choice. We can stop at any time. “Fantasy monsters that incarnate our fears are there for the slaying; while playing, we also play down such physical discomforts as breathlessness, weariness, dizziness, side stitches, and muscle strain. In this way, feats of strength often become acts of devotion, drive, and passion” [35]. Play can make us super heroes of our own life and health [40].

Having **inherent attraction (3)** is a benefit of play because it can provide a motivational context for healing, which traditionally can be difficult [41]. Like play, being healthy is inherently attractive. While being healthy is attractive, the process of healing may not be. Play can help us overcome barriers to healing. Healing is a process that can take a lifetime—and the slow progress can be extremely frustrating[42]. Thinking about the time we must invest to achieve a certain level of health can be overwhelming. Play puts us in a **state free from time (5)** or in a state of flow [43, p. 87]. It can help us forget how far we have to go and focus on what we are doing now. Play helps us through the process of healing and alleviates the dread of the distance we must travel. But play is more than flow—it reserves poise for those who “Experience increasing dimensions of dignity, grace, composure, ease, wit, fulfillment, and spontaneity"[35]. Play can keep us on track to improved health.

Play **diminishes our consciousness of self (6)**. Healing can be awkward. It might require moving in strange ways or breaking social norms, but play can provide a context that alleviates feeling weird (e.g., [44–47]). We are more willing to try new things in play because it is not our true selves. In almost all forms of therapy and healing, there are multiple approaches one can take, which play affords because it has **improvisational potential (7)** and supports a diverse range of healing styles (e.g., [48, 49]). We may find that those new things are the very solutions we need to heal. We may learn about our self and about new ways to heal in the process. Play allows us to find solutions that we may not be willing to try otherwise. Biologically speaking, this is probably why play is valued in natural selection—it makes us (all animals) healthier and versatile.

2.2.2 Healing is a Process Towards the Good Life

Perhaps the single most important reason play is a natural vehicle for healing is that both are a process. Healing is one aspect of developing ourselves toward Eudaimonia. Eudaimonia is the lifelong development of a self-determined human [50]. It is less about the destination and more about the process of realizing our idealized (Healthy) selves. The theological aspect of the good life is particularly important as it establishes that to live a good life, we must find our true purpose and practice it [51]. The constructivist aspect is that we must act to develop the

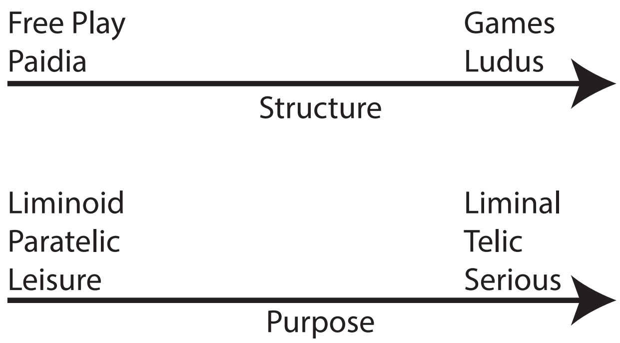


FIGURE 2.3: Vocabulary describing properties of play and games

good life [52]. “The good life is not a passive state or a situation that can be identified, but a process toward an end in which actions and activities constitute the meanings of a life well lived. The good life is a process of acting and reflecting with the purpose of improving ourselves" [52]. Play can also be thought of as a process where we naturally improve ourselves. Healing is intentional, much like the Eudaimonia.

2.2.3 Serious Play for Health

In thinking about play as a natural vehicle for healing, it is beneficial to distinguish between the telic and paratelic reasons we play. Telic play is a serious mindset where we engage in play for a specific purpose, while paratelic play is a playful state where play itself is the goal [53]. The play I seek to employ is telic, which helps us achieve our goals, grow, and work towards the “Good life" [51], or eudaimonia [52]. When play is telic, it often becomes constrained, contextualized, and structured so that a premeditated purpose is achieved. In this work, that purpose is health, but not necessarily an improvement in a health condition, though that could be an excellent outcome. Improved health can mean many things: improved confidence in one’s abilities, improved abilities, improved mental health, improved social health, or improved physical health. “Health is a condition of well-being free of disease or infirmity and a basic and universal human right" [54]. Health and happiness are tightly coupled.

Serious Play for Health systems are flexible play structures that provide a context to improve a specific aspect of health. They are similar to design probes in that they promote certain behaviors through design affordances but are ambiguous enough to be appropriated in a variety of interesting ways (e.g. [55]). It is likely that a Serious Play for Health system could be used to support a variety of different types of games. Unlike design probes, Serious Play for Health systems can be deployed as finished products where ambiguity and being "unfinished" is a feature that allows many stakeholders to appropriate the product in a variety of contexts to fit their specific needs. The core mechanics that the system affords should focus on a specific skill that would translate into improved health outcomes [56]. Serious Play for Health systems fall in the "Focused Healing" area of Figure 2.2, but are less structured than Serious Games for Health, which are discussed below.

Stakeholders of health include the individual, family, medical professionals, and possibly teachers—each with their own agendas and therefore, different play structures and needs. A medical professional may create vastly different games using the same Serious Play for Health system when they are in a one-on-one office visit versus in a group session. The two different contexts might also require different levels of playfulness, where the one-on-one may be more serious, yet less structured, whereas the group session may require rigid rules and be more game-like to avoid social breakdowns. A Serious Play for Health system would support a medical professional in both of these contexts. At home, where there are many more distractions and potentially fun toys, parents may introduce seemingly extraneous mechanics to keep their child engaged when using a Serious Play for Health system, such as the interesting mechanics and social structures in *Brutally Unfair Tactics Totally OK Now (BUTTON)* [57]. In a day program for adults with developmental disabilities, the Serious Play for Health system may be appropriated in a less childish manner. The true benefit of Serious Play for Health systems lies in their flexibility. This comes at a cost. Data reliability and study of the system becomes much more complex due to the lack of controls. Variables become harder to measure because the questions differ in each context and with each stakeholder population involved. Like play, Serious Play for Health systems can get messy from a research standpoint.

2.2.4 Play Therapy

Using play as a vehicle for healing is not an original idea of this work—there is an entire field of practice called "Play Therapy" [58] that uses play as a communication tool to understand players' worlds and to help them deal with emotional distress and trauma. Play therapy is generally used to help children [59], but has also been used to help adults [60]. Play therapy has been effective for children with schizophrenia, enuresis/encopresis, anxiety disorders, trichotillomania, selective mutism, withdrawn behavior, acting out behaviors, sexual abuse, trauma and neglect, learning/academic problems, and various life adjustment problems [58, 61]. With adults, it has been used for couples therapy, stress management, group therapy for older adults, and psychotherapy [60]. Play therapy tends to focus on the mind's health and social health, but play also has the potential to improve the body's health. The study of play has primarily focused on play in children and animals, but adults play too [62]! Although adults biologically need less play than children (because their brains are no longer rapidly developing), adults without play often become joyless, depressed, and empty [30]. Play carries meanings with significant resonance for older adults [63]. Play is neither frivolous nor a waste of time. "Being playful is the engine of innovation and creativity: as we play, we think about thinking and we learn to act in new ways" [64, p. 19-22].

2.2.5 Games

Structured play inherently leads to thinking about games [65]. It is hard to define games, but they can be understood in the context of play as free movement in a more rigid structure [66] where a game is the most rigid. Playfulness does not need to have the formal structure of games [67]. Like telic and paratelic play, there are varying reasons we play games. The liminal use of games is similar to telic play in that we play for a serious purpose, but we also play games for liminoid purposes which may have serious elements, but that is not the focus [68]. Games are generally beneficial for the same reasons play is generally beneficial. They improve our cognitive and social skills [69, 70]. Games are used to teach us about politics [71], religion [72], experiences of others [73], education [74], and history [75]. Games that are not designed to improve health are still valuable. "Games are not valuable because they can teach someone a skill or make the world a better place. Like other forms of cultural expressions, games and play are important because they are beautiful" [76]. Games have existed almost as long as play. With the rise of technology, games have only become more instrumental in society. We are in the gamer generation [77]. "Like making music, telling stories, and creating images, playing games is part of what it means to be human" [64, p. 19-22].

Games take many forms and exist in many media formats—from tangible board games to technology driven console games [78]. Games can be played alone, with collocated players, or across the web [79]. Their magic circles can exist in your hands, in your living room, in your neighborhood, or around the world [80]. They can be separate from reality or eerily close to real life [81, 82]. You can play as yourself or as someone else entirely [83]. The possibilities are endless, but the universal tie that unties all games is that they have an underlying structure. Structure defines a game's purpose, rhetoric, and play contract.

2.2.6 Serious Games for Health

Naturally, structured play designed to improve health brings about the field of Serious Games for Health [6]. On the paidia-ludus spectrum, where paidia is unstructured free play and ludus are formal games [84], Serious Games for Health tend to lean towards ludus because the word “game" is in the name. The work in this thesis attempts to explore how paidia-telic play approaches compare to more traditional ludus-telic Serious Games for Health. In simpler terms, I want to compare the effectiveness of rigid games versus more open-ended play structures in the context of improving health and happiness. “Focused Healing" in Figure 2.2 illustrates the space this thesis primarily explores. Another branch of Serious Games for Health comprises games that train medical professionals and are aimed at non-patient players, but this thesis is not interested in that aspect [85].

A variety of Serious Games for Health had been documented to be effective for their target populations, and they are very wide-ranging in their platforms, health outcomes, and target populations, including such examples as an exergame to help blind children with balance, [86] embodied persuasive games for adults in wheelchair [87], or mobile games for motivating players toward a tobacco-free life in early adolescence [88]. “Video games improved 69% of psychological therapy outcomes, 59% of physical therapy outcomes, 50% of physical activity outcomes, 46% of clinician skills outcomes, 42% of health education outcomes, 42% of pain distraction outcomes, and 37% of disease self-management outcomes. Study quality was generally poor; for example, two thirds (66%) of studies had follow-up periods of under 12 weeks, and only 11% of studies blinded researchers " [89]. Taken to the extreme, Super Better asks players to look at life as a game with the intent to heal by defining power-ups, allies, and enemies in their own life and gaming the system in their favor quite literally [40].

Games have the potential to offer people with disabilities a cost-effective, personalized, data-driven, connected, and motivating context for otherwise tedious and repetitive therapy. Many of these potential benefits rely on other players and technology, which is discussed in the following sections. Games can be an effective educational intervention and medium to convey and support feelings of self-efficacy due to the immersive and pervasive virtual environment. Games have demonstrated the ability to teach while providing a motivating and interactive environment [90, 91], and can be as effective as face-to-face instruction [74].

Serious games work well for health because they provide a platform and reason to do tasks beneficial to health repeatedly. The core mechanics can be designed for exercise or to provide learning content. Their underlying systems are designed to give us a reason to keep trying [92]. Their experiences, venues, elements, themes, ideas, mechanics, interfaces, story, art, worlds, characters, spaces, aesthetics, communities, technology, and purpose [93] keep us playing; keep us healing.

2.2.7 Play Can Heal Our Ableist Society

Technology design that includes people with disabilities often naturally becomes playful or includes elements of play, which results in novel and interesting user experiences (e.g. [94–97]). In these cases, play emerged naturally, but may not have been sought out directly. I am interested in designing technology that is directly inspired by play. As is true for people in general, people with disabilities are playful [98]. Play and games can serve people with disabilities in numerous ways, including increasing their visibility, improving public perception of people with disabilities, and fostering healthy connections in communities. Public visibility of people with disabilities and designing for social acceptance can reduce stigmas [99]. Negative socio-cultural stigma continues to dissuade people from using their assistive technology [100], isolate themselves, and worry about unwanted attention [101–104]. Oppression of people with disabilities is systematic, political, and sociocultural [4]. Historically, people with disabilities have put in the labor to improve their rights (e.g., the disability rights movement [4]), but all of society should actively participate in the shared responsibility. Play has the potential to make some of this labor feel less like work. In this work, I aim to create playful artifacts inspired by people with disabilities and contribute to a future where these technologies can playfully support societal growth and opportunities for the inclusion of people with disabilities.

2.3 Theme 2: Social Play

"A playful system is a human system, a social system rife with contradictions and with possibility" [2]. When we play with others, the possibility space is greatly increased, becomes less predictable, and is bursting with potential. Some of these social affordances include monitoring, awareness, mimicry, immediacy, reinforcement, verbal communication, and non-verbal communication [79]. As social animals, humans have thrived because there is strength in numbers. Being social benefits our emotional health, our intelligence, and our general well-being. Isbister's *How Games Move us: Emotion By Design (Playful Thinking)* provides examples of social play that is emotionally striking as well as commentary on what elements encourage response, why these interactions are important, and what impact they can have on society [83]. Games represent fertile ground for social play, but less than one third of games for health are multiplayer [85]. Games serve as computational meeting places for diverse populations of gamers including older adults, youth, international groups, and players with disabilities [105]. Social interaction and participation largely explain why we enjoy games [106, 107].

2.3.1 Possible Structures of Social Play

When social play follows a structure, three spectrums naturally emerge: 1) symmetrical and asymmetrical play, 2) collaborative and competitive play, and 3) simultaneous and sequential play [108]. In symmetrical play, all players have the same set of actions and perspectives, such as in many board games like *Catan*, *Monopoly*, and *Risk*. In asymmetrical play, players have different roles, such as in *Keep Talking and No Body Explodes* and *Hotaru* [45]. In collaborative play, players work together towards a common goal, such as in *Code Names*. In competitive play, players try to win or make other players lose (e.g. [109]). In the collaborative and competitive spectrum, the classic distinction between competitive and cooperative modes of play sometimes do not fully transfer to account for the interpersonal dynamics within collocated groups [110]. Sometimes collaborative games have competitive elements. In simultaneous play, players can take actions at their leisure and do not have to wait for their turn, such as in most massively multiplayer online role playing games. In sequential play, players must wait their turn to take certain actions, like in many board games such as *checkers* and *chess*. Of course, play does not need structure to be social and therefore, these three spectrums do not encompass all social play. In fact, the volatile nature of play means that in one session, some of these spectrums may not be experienced. For example, two children might be playing entirely different games while chatting about Mom's cooking. They are both playing and being social, but because the activities are different, it may not be appropriate to categorize their play. In this example, it would be appropriate to categorize their play as asymmetrical (because they are performing different activities) and simultaneous (because they are playing at the same time), but not as either competitive or collaborative.

2.3.2 Health Benefits of Social Play

Coliberation is "A shared transcendence of personal limitations, of our understanding of our own capabilities; a sudden, momentary transformation of our awareness of the connections between ourselves, each other, and the world we find each other in" [111]. Playing with others helps look beyond our current abilities and towards our healing goals. The number one motivation to play digital games, supported by 60% of the gamers asked, is the social component of being able to play with friends [112]. Related to health, is the idea that humans are inherently social—and so too are play and games. It is paramount to think well about how our social relationships are included in the next generation of healing. "Social relationships—both quantity and quality—affect mental health, health behavior, physical health, and mortality risk" [113]. Isbister eloquently says: "Another risk is placing high hopes on games designed for the public good- as many nonprofits, health organizations, and social enterprises are doing-without realizing the bad game design can undermine the most noble of ambitions. It's quite possible to make terrible, dull, and unappealing games for learning or training or health" [83]. In the rhetoric of nudging, or changing our behaviors, such as health choices, humans are social animals [114]. We "depend on others and are driven by social influence; we are guided by emotions, not just reason; most of our everyday behavior is habitual, not consciously planned; and even where rationality holds, it is bounded" [115]. From a behavioral standpoint, social relationships affect our health because they influence, or control, our health habits, such as eating healthy or exercising [116].

A great example of an asymmetrical collaborative Serious Game for Health is for stroke rehabilitation, where one player is driving a race car, but the stroke survivor is moving their weak arm in a therapeutic sweeping motion to activate the windshield wipers so the driver can see where they are driving [117]. One of the benefits of this include the availability of mechanics that are appropriate for each player's ability and a codependence between players. A good example of a symmetrical competitive Serious Game for Health is a wheelchair-based room-sized air hockey game where players of different abilities can compete on a level playing field [118]. Both of these examples are simultaneous. An example of an effective sequential Serious Game for Health is this competitive turn-based game mode for rehabilitation of patients with Parkinson's disease: [119].

2.4 Theme 3: Technology

We live in a world of systems and this ludic century is an era of games [76]. Society and technology are tightly coupled. From the advances of factory machines in the industrial revolution to cloud computing, the very way we live and work is driven by advancement in technology. We drive technological advancement, but it drives and shapes us as well. Keeping time and working business hours are a result of efficient factory production, but we engineered factory equipment to revolutionize textile production. All of a sudden, artisanship and how we consume goods would be forever changed because of advances in technology. This gave us time to pursue other passions, but skilled craftsmanship was replaced in many ways. Our perceptions of crafters and artists changed as a society. Data now changes us in similar ways. Our decision-making process is actively being affected by recommendations made by algorithms, data, and machine learning. We no longer need to remember addresses to write letters, phone numbers to contact our relatives, or directions for navigating the town we were raised in. Our daily schedule, our decision-making process, and our memory have all been changed because of technology. But we developed and adopted these very systems, so we must see inherent value in the way technology is developed. Humans and technology drive each other. Technology is pervasive in all aspects of human life including our health, communication, politics, consumption, economics, transportation, and entertainment such as games.

It is easy to hate technology for all of the negative consequences it has brought about. We have a habit of releasing "innovative solutions" before we think about how they will affect the world. Sometimes it's great, sometimes it's not. However, the real issue lies in the pace of innovation; politics, policy, and ethical considerations can not reasonably keep up with the explosion of tech and data. Technology has massive potential to improve our lives, our social relationships, and our health—we just have to slow down and think about *how* it should be implemented to serve us better.

2.4.1 How Technology Affects our Social Relationships

There is a common trope that people are too addicted to their devices and are not as present as they used to be, but before screen media, there was written media—newspapers and books to bury our faces in on the subway. "Americans are not as isolated as has been previously reported. We find that the extent of social isolation has hardly changed since 1985, contrary to concerns that the prevalence of severe isolation has tripled since then. Only 6% of the adult population has no one with whom they can discuss important matters or who they consider to be 'especially significant' in their life" [120]. The quantity of social interactions is certainly not less than before. However, the quality, diversity, and richness of social interactions has changed. "Americans' discussion networks have shrunk by about a third since 1985 and have become less diverse because they contain fewer non-family members. However, contrary to the considerable concern that people's use of the internet and cell phones could be tied to the trend towards smaller networks, we find that ownership of a mobile phone and participation in a variety of internet activities are associated with larger and more diverse core discussion networks" [120]. With careful thought, technology can be designed to augment and enrich social interactions. For colocated interactions, technology can be designed for less screen-centric interventions that promote face-to-face interactions, such as in *yamove!* [109], it can signal the amount of touch that players are comfortable with, such as in *True Colors* [121], and can promote balanced contributions for group discussions, such as in *Lågom* [122]. In social situations that occur over long distances, technology can augment social super powers, affording us abilities that we do not have in real life [123, 124]. Digital affordances have the potential to promote healthy social interactions. The same digital affordances may promote play that can improve the healing process. For example, technology can enable players with diverse sets of abilities to play on a level playing field [118].

2.4.2 What technology has to do with healing

Technology's role in health, games, play, and social interactions is undeniable—the human species has thrived in many ways due to our technological advances—from fire to smelting to silicon [125]. Advances in technology have led to the rise of serious games and gamification [126]. Technology is used to deliver serious health systems for many reasons, including its potential to offer people with disabilities a cost-effective, personalized, data-driven, and connected context for healing.

Technology can be a cost-effective intervention for health because of its scalability. The same system can be delivered over app stores and the web to a diverse range of devices that have become ubiquitous to our society. Mobile devices and health systems are potentially promising tools to change health-related behaviors and manage chronic conditions [127]. If the systems are software based and do not require specialized hardware, the cost to deliver these solutions is extremely low. Using telecommunications technologies to improve healthcare delivery across distances is the telephone of tomorrow and will only be enhanced by substantive research proving its impact on healthcare outcomes [128]. While technology should not be used to replace time spent with medical professionals, it is certainly much cheaper (or should be) than our extremely expensive healthcare system.

Technology can help deliver personalized health curricula. It can be designed to automatically adjust the challenge based on performance [129]. These dynamic curricula have the potential to deliver appropriately difficult content without being overly frustrating. They also benefit from the ability to deliver content that is suitable for the individual at a given point in time in their healing process. Developing dynamic systems as described can be extremely difficult because they must either be data-driven or premeditated. Data-driven examples often use machine learning to predict appropriate content, which means a lot of data is needed and the data needs to accurately represent a population's need without bias. Premeditated examples occur when medical professionals work with technology makers to model curricula at different points in time in the healing process, but this is difficult because medical professionals are very busy and expensive and the work is very interdisciplinary. The best approach is probably a hybrid between the two, where a system is designed with medical professionals and is designed to collect clean data that can be used for future improvement.

Technology is often data-driven, a characteristic that can benefit health systems. These systems can use the data to both improve their content delivery and to inform stakeholders of usage. Additionally, logged performance may offer insights about progress in the healing process. Data collected by these systems can be used to train machine learning models that have been designed to represent users of the specialized technology. These models can iteratively improve the system's sensing abilities and help deliver appropriate performance insights for individuals when a medical professional is not present. Data from these systems can also be used to bridge the gaps between medical professionals—they can see a player's individual data to help make informed decisions backed up by the quantified self [130]. Of course, what we choose to log and how it is stored and retrieved is incredibly important [131].

Technology allows us to be connected. The connected learning framework [132] is designed to improve learning, but it is also useful for health. It has four design principles: everyone can participate, learning happens by doing, challenge is constant, and everything is interconnected [132]. Experiences invite participation and provide many different ways for individuals and groups to contribute [132]. In the context of Serious Play for Health systems, the flexibility to support many contexts and stakeholders aligns with the principle that everyone can participate. Learning is experiential and part of the pursuit of meaningful activities and projects [132], but this can also be applied to healing. To heal, we must be open to trying new approaches. Interest or cultivation of an interest creates both a "need to know" and a "need to share" [132]. Play cultivates our interest. Working with medical professionals requires us to learn and share. Technology affords the interconnectedness of the connected framework. People who are provided with multiple contexts for engaging in connected healing—contexts in which they receive immediate feedback on progress, have access to tools for planning and reflection, and are given opportunities for mastery of specialist language and practices—are more successful in learning [132] and in healing.

2.4.3 Humans in the loop

Sensing algorithms used in therapy games can be overly critical and frustrating for some players due to limitations of technology and diverse player abilities. While the system is a crucial feature for facilitating healing at home, trained medical professionals who may want to use it in their practice are more suited to accurately grade health. Supporting low cost game controllers to be used in lieu of system choices can keep the human in the loop for more accurate grading or to keep the player from being frustrated. With a controller connected to the device, stakeholders can remotely signal systems to consider performance good, or bad, as well as make other choice-based interactions that currently rely on the system. Many therapy games and technical systems rely on sensors, smart algorithms, and clever programming to facilitate therapy and gameplay, but a more effective solution would be to support both sensors with clever algorithms and the surrounding expertise from experts. The benefit of supporting a controller is to use Wizard of Oz [23] techniques to seamlessly let a facilitator override the system. I can also design for when unanticipated audiences use the controller. By gracefully transitioning between the control of the sensing system and the game controller input from a facilitator, Serious Play for Health systems can be played by those whose actions are unrecognizable to the system, those who have hardware that is too slow, and those who may be frustrated by an overly critical algorithm. While the technical implementation of supporting most commercial game controllers is not overly difficult due to frameworks provided by Apple and Android, there will be some design challenges. The controller interactions must be designed with a scheme that is intuitive for the facilitator and invisible to the player. The input from these controllers is also valuable data that can be collected to inform updates to the sensing algorithms themselves.

From the arts and humanities perspective, we know that technology is more than arithmetic, algorithms, and data [133]. It is more than computer science, engineering, and math. It is more than input and output. We should pursue "software-based methods to invent and interrogate statements of assignment, connection, equivalence, and identity" [133].

2.5 Ethical Considerations

Play, games, technology, and our social relationships have the power to help us heal. When we design systems, we must ensure we think well about who the system actually helps. People do not need to be fixed. They need to be supported in pursuing their goals. Designers of technology are in a uniquely challenging and important position to commandeer the technologies around us and the technologies

FIGURE 2.4: "Bad play" is a natural characteristic of play due to its volatile nature

under development to support a future that is in the best interest to society—not personal gain at the expense of others. In the previous sections, the potential of play, games, technology, and social interactions have been discussed in the context of healing. If designed without careful thought and study, these very potentials can become detrimental to our health or our society's well being. The ethical considerations for each of the themes discussed below are extremely important, but are not exhaustive.

2.5.1 Play and Games, but Evil

Play is not always good and productive. When thinking about play, many may not consider "bad play" [53]. This kind of play can be transgressive, disruptive, disrespectful, and rules-defying [134]. Play cannot be controlled and therefore is susceptible to negative outcomes. Play with the dog in Figure 2.1 may quickly look like Figure 2.4. Pragmatizing play is risky. Therefore, the rigidity of games is often used to limit the potential for evil play. Limiting play's potential for evil also limits its potential for good. Serious Play for Health systems may be more susceptible to evil play than Serious Games for Health.

Serious games do not mitigate all ethical concerns because they are less susceptible to evil play—their rigidity creates a separate set of ethical concerns. Games can be used to persuade us in many ways including our political views, religious beliefs, and interpretation of the world [135]. If the procedural rhetoric is not designed well, the meaning can be lost or even harmful [135]. Games transform our understanding of and the actual construction of our personal and cultural identities [136] and their malleable rules can change culture itself [137]. Much of the reason games can change our behavior can be explained through behavioral psychology. Many of our behaviors can be controlled through controlling the environment [138]. This environment may be viewed through the lens of the magic circle [80]. "Behavioral psychology is utterly non-esoteric and supremely pragmatic in its approach" [139]. This is at the root of the ethical issues of gamification. Play and games cannot be designed to be wholly pragmatic or they become instruments of capitalism. This is one of the major critiques of gamification.

Gamification has polarized many academics who argue in *The Rhetoric Wars* that gamification is a desecration of the very nature of games and play [140]. "I believe whole-heartedly that wonderful things can happen when people play. But gamification advocates do not preach the beauty and power of play. Perhaps without knowing it, they're selling a pernicious worldview that doesn't give weight to literal truth. Instead, they are trafficking in fantasies that ignore the realities of day-to-day life. This isn't fun and games—it's a tactic most commonly employed by repressive, authoritarian regimes" [141]. Gamification as badges, leadership boards, and generalized re-skinning is shallow and will not lead to improved health outcomes—only well-designed specialized systems can hope to. In the above sections, I discuss how technology can collect data for improved models, but this exercise can be dangerous. "Playbor" or play labor [142] exploits gamification to pursue capitalistic gains. If the goal was to sell the model, this would be entirely problematic because the very nature of the model creation then changes to accommodate a profit. The interest of the player and society at large should always be the center of the decision-making process.

Games are such a powerful motivator that non-game activities designed to look like games, i.e. gamified systems, have attracted the attention of many [126]. This is true for tedious and otherwise non-interesting activities (Burke, 2016). By adding game design elements to a pre-existing activity, designers manage to engage people more with this activity [143]. However, traditional gamification approaches have been widely criticized [144]. Ethics apart, just adding superficial game-looking elements to an otherwise tedious activity does not work in the long run. Both Nicholson and Mcgonigal [144, 145] have pointed out that extrinsic rewards like those typically used in gamification decrease intrinsic motivation and engagement after the initial novelty effect. McGonigal suggests a more fruitful approach by making the activity intrinsically motivating and the rewards meaningful to the player [146].

The effectiveness of gamification has also been called into question. "Instead of helping the public to identify and align around systematic social issues, games and gamified platforms for health, education,... let people 'feel as if they're doing something worthwhile"' [141]. Even if gamification quantitatively improves some condition, it may not be doing so in a manner respectful to play or the player. "The irony of instrumentalizing play and games as means to another end, then, is that it depletes the very source it tries to tap into: the experience of autonomy in noninstrumental activity" [115]. Sometimes, even with the best intentions, gamification can be dangerous. For example, DietBet is a social gaming website that uses financial incentives and social influence to promote weight loss. Players bet money and have 4 weeks to lose 4% of their initial body weight or they lose their money [147]. 'Winners' split the money pool and are effectively paid by those who were unable to lose 4% of their body weight in 4 weeks. While the site successfully promoted weight loss, it is unclear if the gambling promotes unsafe dieting practices or even increases the risk of eating disorders, factors that are not mentioned in the research.

2.5.2 Toxic Relationships

Play is often social. Play can be evil. Social play can be negative. Some reasons social play can be negative include trolling, bullying, and misinformation, but there are others. Serious Play for Health systems are not immune to the negative discourse we often find in multiplayer games, such as trolling. Trolling is often made possible by anonymity and is a snowballing phenomenon, where being trolled creates trollers [148]. Anonymity online is important for free speech and it may be important in Serious Play for Health systems for players who desire privacy about their health. In the context of health and abilities, people, especially children, are often bullied. Poking fun at peoples' disabilities is detrimental to the healing process. Also detrimental to healing is misinformation, even if the source had the best intentions. Many toxic social interactions are an abuse of the system affordances, system misinformation, or misinterpretation. Systems can build communities and evolve over time. It is up to the system designers, policy makers, and communities to evolve in a way that promotes healthy social interactions and relationships. Serious Play for Health systems are appropriated by stakeholders who are invested in users' health and are more likely to be colocated than online. Players and system builders must make deliberate effort to foster a social environment that is conducive to healing.

2.5.3 Privacy, Colonizing, and Bias Issues in Technology

In the next generation of healing, technology will remain a crucial crutch, but we must think critically about how it is designed and who it helps. Technology is becoming more and more data driven with the advent of machine learning and artificial intelligence. These very systems are engineered to find patterns, make predictions, and surface trends that exist in data. A common critique of this practice is rooted in the way this technology polarizes us into categories determined often by technologists and statisticians. This can become problematic in a health context because people with disabilities often do not fit into these ableist categories. These systems are often black boxes that reverse-engineer the biases in our data and augment our societal problems. These systems need to be trained on a diverse set of data from a diverse set of representative people who use the system, transparent in their decision-making process, and trained in a way meaningful to the end user. Many of these systems are built to normalize us—especially in the context of healing and often not how we want to heal. A more participatory approach to data collection, machine learning, validation of the models, and design of systems around these models is needed. People with disabilities, marginalized populations, and minorities should be able to use the technology and benefit from its use in the same ways that everyone else does. The data collected to train these systems must be handled with the upmost respect, security, and transparency.

Chapter 3

Guiding Questions and Methodologies

In this chapter, I provide the overarching methodology that guides my research. Each project within this thesis utilizes project-specific methodology which is described in the respective chapter. In the Introduction, I framed my research as a Wicked Problem. Play and Games for Health exist in the space of Wicked Problems because they interact with and change our society. Understanding how these systems will impact, interact, and integrate with healthcare systems, stakeholders, and players around the world requires careful and well-informed design and reflection. Serious systems for health interact with cultures, ethics, healthcare, education, philosophy, and more. To keep a more reasonable scope, this dissertation focuses on some of the approaches one can take to design technology for health.

3.1 Guiding Questions and Contribution

In the following chapters, I take numerous approaches to the design of games for health. SpokeIt, described in Chapter 4, was originally designed using a therapy-first approach favoring the medical model, but later was shifted from a structured game subtly into the play spectrum. Spellcasters, described in Chapter 5, took a game-first approach originally designed purely for entertainment and was re-engineered for therapy. Cirkus, described in 6, is an open-ended play structure designed with a community model rather than the medical model. Each case utilizes machine learning in differing strategic ways. There were many lessons learned and emerging methodologies that resulted from this design work. Reflecting on these lessons and methods led to multiple reframings [18] that led to the formulation of the overarching guiding questions that this dissertation aims to explore. The specific guiding questions that drove this work are:

GQ1: *What considerations should one make when deciding between a health-first approach versus a game-first approach?*

GQ2: *What considerations should one make when deciding between an open-ended play approach or a closed-game system?*

GQ3: *How can we design play for health that supports us socially and emotionally?*

GQ4: *What role should machine learning play in applications that support people with disabilities*

The first question is concerned with the design angle that is given more weight at the beginning of the design process. In a completely health-first approach, the medical model is often employed to ensure that the technology can lead to quantifiable improved health outcomes. In this approach, medical professionals may wield more decision power than the intended players. The mechanics are designed to heal and are then gamified [64] to create a motivating context for completing therapy. On the other side of the spectrum is a complete game-first approach where entertainment goals take center stage and are retrofitted for therapy later in the process. It is quite possible to achieve desirable results at any point on this spectrum and it is unlikely that any project lives entirely on one pole.

The second question is concerned with the amount of structure the technology should provide. In a closed game system, the technology mediates the entire experience and accounts for all of the affordances of the magic circle [149]. There are many examples in the domain of Serious Games for Health that employ a closed-game system approach [6]. In an open-ended play approach, players have the power to spontaneously change the rules and style of play because the technology is intentionally designed to be somewhat ambiguous. The ambiguity of these technological probes affords flexibility in a diverse set of contexts so players can decide how to appropriate the technology. Much like the first question, it is unlikely that any technology truly lives entirely to one side of the spectrum.

The third question is concerned with design methods that enable us as designers and technologists to create playful health systems that authentically serve the populations they are intended to benefit. A recent survey of ASSETS and CHI accessibility work showed that only 16 methodological contributions (3.2% of all) have been made to the accessibility community since 1994 [3]. This research aims to add procedures behind developing research agendas that are genuine, meaningful, impactful, respectful, and celebratory of disability power, pride, and resistance.

The fourth questions is concerned with how machine learning can be ethically and effectively integrated in health systems. Machine learning is often used in this domain [150–152] but has the potential to be the source of issues of biases, transparency, accountability, and misrepresentative use cases [10, 153, 154]. The normative nature of machine learning [155] can potentially unfairly affect populations of people with disabilities [10, 156] because of how the data is collected, used, and tagged for training the models [157].

The contributions of this dissertation are two-fold: applied and methodological. The systems I build are designed to benefit the populations they were made with and for. Through the creation of these technologies, knowledge was generated. The experience of building these artifacts is a valuable contribution to humanity. Through reflecting on their development, conceptual advances towards answering the research questions of this work can be made. Future playful health system creators may benefit from the shared account this dissertation represents. Furthermore, I contribute methodologies that are a result of the applied research I conducted. I employed these methodologies to create case studies that support their novelty, which is also presented in this dissertation. Both the applied and methodological contributions of this research represent progress towards improving the status of the Wicked Problems this work set out to improve.

3.2 Methodology

Although each case study employs its own set of methods, which I define in each respective chapter, my overall research employs a set of overarching methodologies to poke at a broader set of research questions, namely how we approach the design of playful health systems. There is no way to completely solve the Wicked Problem this dissertation focuses on, but applying a RtD approach allows me to articulate its contributions.

3.2.1 Research through Design

Donald Norman coined "user-centered design" in the 1980s, and the practice has since exploded in popularity [158]. Jakob Nielsen laid the groundwork for a more generalized method to produce heuristics for usability engineering that would prove to be useful beyond computer software design [159]. Both Nielsen and Norman's work explore the needs and desires of users and involve them in the design process. This led to the common practice of usability testing. That process of involving users came to be known as usability testing. Usability testing focuses on user needs, employs empirical measurement, and supports iterative design [160]. Research through Design is a method of inquiry into improving the state of Wicked Problems [2, 161] and is discussed in section 3.2 below.

In RtD, researchers generate new knowledge by understanding the current state and then suggesting an improved future state in the form of a design, which involves deep reflection and iteratively understanding the people, problem, and context around the situation [2]. Additionally, RtD is a research approach that employs methods and processes from design practice as a legitimate method of inquiry [162]. Research through Design lends itself to addressing Wicked Problems through its holistic approach of integrating knowledge and theories from across many disciplines and its iterative approach to reframing the problematic situation and preferred state as the desired outcome of the research [162].

Research through Design serves as the backbone to this dissertation's contributions. I create designed artifacts and reflect on the process of their creation. Through this reflection, I co-founded two design methods to potentially aid future designers in this space. I collaborated on case studies that employ these methods and reflect on that process. Therefore, RtD is an apt method of inquiry for my research. Within RtD are a multitude of design practices. In the following subsection, I describe participatory design, which has been formative in my work.

3.2.2 Participatory Design

Participatory Design (PD) builds on three premises: (1) Its goal is to improve the quality of life, rather than demonstrate the capability of technology; (2) It is collaborative and cooperative, rather than hierarchical; and (3) It values interactive evaluation to gather and integrate feedback from intended participants, thereby promoting design iteration [163]. Further, it is critical to PD that designers embrace the values, history, and context of the situations they design for, so that new technologies respond to them [163].

Although it originated as a political movement aimed at improving workers' quality of life in the workplace [22], PD is currently employed in many areas of design [164], ranging from service design (e.g.[165]) to HCI (e.g. [166]) or social design (e.g. [167, 168]). Participatory Design has also been used in the design of technologies to support populations with developmental disabilities. In their research for designing movement-based play with young people using powered wheelchairs [97], Gerling et al. outline examples of projects that utilized PD with children and young people with disabilities, including children with autism [169] and young people with learning disabilities [170].

Although PD is not a dominant approach in game design [171], some designers have leveraged PD methods to design games [172] that better respond to their players' needs, such as serious games revolved around numerous mental health conditions [171]. There are several serious games that benefit both children (e.g. a game to teach computational literacy using tangibles [173]) and adults with developmental disabilities (e.g. a VR game that teaches social skills [96]).

There are many PD frameworks [174] that are useful in organizing methods, approaches, techniques, tools, and toolkits [175]. I am particularly interested in those that focus on making accessible tools, techniques, and methods designed specifically for people with disabilities [176, 177] in the context of games [172, 176]. Of special importance is the framework utilized by Ellis and Kurniawan for employing PD among populations with specific usability and accessibility requirements [21], as adapted from the five steps defined by Good [178]. This framework is useful because it is broad enough to apply to the domain of Serious Games for Health, while forcing us to think about the populations we are designing with. There are many works that have successfully used and adapted this framework, such as system for better interactive health communication [179], ubiquitous computing systems [180], and an Internet-based information system for aging services professionals [21]. The framework, which guided my work, serves as an outline in our PD sessions. The framework proposes six guidelines, or steps, to conduct PD sessions with populations with disabilities, which I summarize below. The first three steps are performed in preparation for rapidly proceeding through the latter three steps, which comprise of design, feedback, and iteration:

Build Bridges

The first phase is to build the relationships necessary to connect target participants with designers. The participants should be representative of the populations that will use the product. When working with people with disabilities, these bridges are often places of convenience, such as clinics and day programs.

Develop User Model

A user model is a representation of the needs, capabilities, and limitations of participants that will drive design decisions. Traditional PD uses ethnographic techniques to develop the user model, but when working with populations that are difficult to find, a survey, direct interaction, and literature are beneficial.

Map Possibilities

The objective of this phase is to contextualize the goals of the session. The experiences and perceptions of the participants are invaluable when finding what use cases and features are most important to them.

Develop Prototypes

Prototyping in PD is a process where participants inspire the design of an artifact: first through ideation methods such as sketches, brainstorming, and bodystorming; and then through more high-fidelity artifacts.

Elicit and integrate feedback

The iterative nature of PD requires frequent participant feedback. As prototypes are developed, participants should be given the opportunity to experience the system and their feedback should be incorporated into future iterations.

Continue the Iteration

Iterations should continually be developed, and participant feedback should persistently be collected and incorporated. When all the functional requirements and use cases have been designed in a way that is satisfactory to the participants and involved parties, the artifact is ready for release and future updates.

3.2.3 Challenges with Participatory Design

Participatory Design (PD) [22, 164] can empower people with sensory, cognitive, or social impairments to actively take part in the design process of a system [181]. Therefore, PD methods enable collaboration with the intended population and can improve the design and development of software for people with special needs or disabilities [182]. The high rates of assistive technology abandonment are due, in part, to the inability to take populations' perspectives into consideration [181]. This poses the question: if user input has proven to be valuable to assistive technology design [176, 177], why are many systems designed without leveraging it? While we suspect there might be many reasons, the numerous challenges to implementing PD are a major factor [183].

There are many documented pragmatic challenges designers have faced when working with busy medical professionals [184, 185], burned out staff at day programs for individuals with developmental disabilities [186], and children [187]. I faced many of these challenges while co-creating systems. In an effort to stay true to the values of PD and work within our pragmatic constraints, we drew inspiration from digital rapid prototyping techniques often used by industry [188] and marketing [189]. I found that, by using these tools, our entire PD process could accommodate our pragmatic constraints. We illustrate our approach through sessions conducted with the target populations in their respective chapters.

Participatory Design can be very helpful for designing software to improve health and provide therapy for people with disabilities. However, traditional PD methods are often difficult to implement, due to pragmatic constraints. In this thesis, I will present insights into augmenting traditional PD practices with the latest tools and tech to rapidly iterate in medium fidelity with people with disabilities. I have conducted numerous rapid PD sessions with adult participants with developmental disabilities and children with speech impairments, culminating in co-creation of 3 Serious Play for Health system prototypes. I will share my experience of conducting PD sessions within given constraints, discuss using rapid prototyping techniques in a PD context, and share insights into working with adults and children with disabilities.

Chapter 4

SpokeIt

4.1 Introduction

In this chapter, I present SpokeIt [20, 24, 190–193], a speech therapy game designed to support children born with an orofacial cleft that has been surgically corrected [194]. SpokeIt is the result of a grant supported by the National Science Foundation [195] and is the primary project I was brought on to build and research at the beginning of my doctoral appointment. In this chapter, I provide the motivations for developing SpokeIt, the lineage that led to its development, the iterative participatory design of the game, details of implementation, a reflection on the product, and future directions.

4.2 Background

Correcting speech is an important issue because people with speech impairments such as cleft lip or palate are at high risk of behavioral problems and depression [196]. They show more deficits in social and academic competencies, score higher for social problems [197], and are more likely to be teased in social settings [196].

Those who undergo a corrective surgery tend to display a delay in scholarship, have a lower income, marry later in life, and become independent from their parents significantly later [198]. Unfortunately, access to speech therapists is very limited globally, especially for those in a lower socioeconomic status [199]. In 2012, nearly 8% of children aged 3-17 years in the United States had a communication disorder and younger children, boys, and non-Hispanic White children were more likely than other children to receive an intervention service [200].

Speech practice at home is usually hindered by a lack of intrinsic motivation due to the tedious and repetitive idiosyncratic nature of speech therapy curricula [201]. Parents and caretakers experience major difficulties prompting individuals to complete speech exercises at home, especially when young [202]. Parents and caretakers lack the expertise of a speech therapist and report, in general, a low sense of competence with regard to facilitating curricula [203]. Furthermore, English is often not the first language spoken at home. Games and play have been widely recognized as valid motivators for improving health outcomes [204]. The viability of technology-mediated speech therapy for those who do not have regular access to a speech therapist has been explored with promising results [205].

Speech is a crucial skill for effective communication, expression, and sense of self-efficacy. Speech impairments often co-occur with developmental disabilities such as autism spectrum disorder [206], cerebral palsy [207], and Down syndrome [208]. The prevalence of speech impairments in individuals with developmental disabilities has been as high as 51% [209]. Each of these developmental disabilities exhibit symptoms of an articulation disorder. An articulation disorder or a phonological disorder is defined as a difficulty in producing speech sounds that constitute the fundamental components of a language [210]. Speech is a skill that can often be improved with individualized therapy and practice [211, 212].

4.2.1 Functional Requirements

The work in the NSF lineage project (award #1617253: "CHS: Small: Game for Cleft Speech Therapy") began with interviews from stakeholders including speech-language pathologists (SLPs), a plastic surgeon specializing in facial reconstruction for clefts, developmental psychologists, children with clefts, their parents, adults with developmental disabilities co-occurring with speech impairment, stroke survivors, and caretakers. Early in this work, four functional requirements for the proof of concept (POC) were defined by the stakeholders:

- It must be a game
- It must be able to critically listen to speech
- It must work offline
- It must run on mobile hardware

The POC must be a game because a game has the potential to independently facilitate speech therapy, be engaging to promote regular practice, and alleviate the responsibility of parents and caretakers. It must be able to critically listen to speech and provide feedback on how to improve, which introduces many technical issues because major speech recognition APIs that power voice assistants, such as Google Assistant, Siri, and Cortana, are trained to be as forgiving as possible while, for the purpose of speech therapy, accurate detection of speech impairments would be critical. The POC must function offline because many of my target users are from lower socio-economic statuses and do not have regular access to the internet at home. The POC must function on mobile hardware because mobile technology is ubiquitous, affordable, and supports a wide array of sensors and features suitable for delivering therapy; additionally, my target population is more likely to own a mobile device than a computer [213]. These functional requirements became the basis of the competitive analysis described in the following section, Section 4.2.2.

4.2.2 Speech Therapy Applications

Table 1 summarizes my competitive analysis for speech language apps that are available for public use. Sayin' It Sam is the only other mobile application featuring a speech recognition system identical to the library upon which SpokeIt's critical recognition is built. Sayin' it Sam is primarily focused on motivating non-verbal children to speak and is therefore trained to be very forgiving. SpokeIt, however, is built to listen critically to speech and to be used as an articulation therapy tool.

Other researchers have integrated speech recognition into non-mobile interactive game environments to improve literacy. Project LISTEN is an automated reading tutor aimed at helping children learn pronunciation and proper speech when reading aloud. It does this by analyzing various aspects such as pitch, speed, and pauses. Researchers have tested the system in India for assisting children learning English as a second language, as well as in Canada for children looking to improve their speaking skills [214].

Project ALEX is a non-mobile application that has proposed a very robust application for language learners of any age. Project ALEX focuses on a large dictionary with text-to-speech functionality. Most importantly, Project ALEX included pronunciation practice and used speech recognition to check if the user says the work correctly using Microsoft SAPI [215]. Project ALEX is focused on studying the cultural differences in speech and dialect.

Articulate it! is a unique multi-player mobile application created by a SLP specifically to help children improve their speech sound production. Articulate it! employs over 1000 images selected for working on English consonant sounds at the word and phrase level and has the ability to store data for multiple patients. Articulate It! also has multiple game modes such as a phonemes mode where the facilitator can select target sounds and a mode where the facilitator can focus on words with a specified number of syllables. Once a mode is selected, the facilitator has the option to customize the dictionary of target words by removing unwanted ones. Modes can be switched without ending a session and speech can be recorded for later comparisons and for the player to listen back to their speech. This app requires a facilitator to score speech.

Articulation Station [216] is a novel mobile speech therapy app that allows SLPs to customize target sounds and sound placement for patients of all ages to practice. For example, SLPs can make the app focus on /k/ sounds that occur at the beginning, middle, or end of a word, such as cat, pickle, or tick. The app has three levels of difficulty where users must say target words, sentences, or full stories. Like Articulate it!, Articulation Station requires a SLP or facilitator. Here, they grade speech, which is recorded in the app and available for reporting. The app has pre-recorded samples of correct speech for all target words. Articulation Games is a comprehensive, flexible, and fun speech-therapy app for iPads that was created by a certified speech and language pathologist for children to practice the pronunciation of over forty English phonemes, organized according to placement of articulation. It includes thousands of real-life flashcards, accompanied by professional audio recordings and ability to record audio. Players practice phonemes through activities like memory games and flashcards. Articulation Games requires a facilitator to grade speech. Auditory Workout, Articulation Vacation, and Real Vocabulary all offer similar features and experiences as Articulations Games, Articulation Station, and Articulate It!.

Many apps have more features than these presented above, such as data collection capabilities for progress reports, the ability to record players' voices so they can listen back, and settings that allow selecting specific sounds to focus on. SpokeIt did not have these features for its proof of concept, but does in its current form.

In my competitive analysis, I could not find any pervading technology that meets the functional requirements of my stakeholders: an offline critical speech therapy

	Mobile	Critical Speech Recognition	Self-Described Game	Offline
Sayin' It Sam	✓	✗	✓	✓
Articulate It	✓	✗	✓	✓
Articulation Station	✓	✗	✓	✓
Project Listen	✗	✓	✗	✓
Articulation Games	✓	✗	✓	✓
Auditory Workout	✓	✗	✓	✓
Articulation Vacation	✓	✗	✓	✓
Real Vocabulary	✓	✗	✓	✓
Project Alex	✗	✓	✗	✗
Smile Train	✓	✗	✓	✓
SpokeIt	✓	✓	✓	✓

TABLE 4.1: Competitive Analysis for Speech Language Apps based on functional requirements

game that runs on mobile hardware. SpokeIt was designed to fill this gap. The critical speech technology, the hybrid game structure, and the lip-sync animations are features unique to SpokeIt and will make it a competitive service. SpokeIt will potentially benefit those with reduced access to therapy, parents, and caretakers who are not comfortable leading a speech curriculum, and medical professionals who wish to receive progress reports of speech therapy practice at home.

4.2.3 Summary of SpokeIt's Design

SpokeIt is the successor to the PhD work of Zak Rubin [217], who created two speech therapy game prototypes. One prototype took a storybook style approach much like Dora the Explorer, while the other took an arcade game style approach. Each had pros and cons, which I discuss in section 4.3. SpokeIt combined both approaches to form a hybrid structure, which was favored in a comparative study [20]. In the comparative study, SpokeIt was favored for the updated colorful art style and character animations featuring lip sync. While the same underlying speech recognition system, RapidEars, was used in all prototypes, Rubin's interaction design was more advanced at the time. Though SpokeIt fared well in the comparative study, the speech system was frustrating and it became evident that a more participatory approach was necessary. I ran PD sessions with adults with a diverse range of developmental disabilities co-occuring with speech impairment. These populations were chosen over the intended population of children with cleft speech because of convenience and to diversify the target audiences. The design session included focus groups, paper prototyping, affinity diagramming, and rapid medium fidelity prototyping in Adobe XD. This session resulted in four medium fidelity designs, which are discussed in the Section 4.4.

In an attempt to make SpokeIt work on a diverse range of platforms, such as Android devices and PCs, we attempted to port the game into the Javascript game engine, Phaser, and use Pocketsphinx.js, which is a JavaScript implementation of the tech underlying RapidEars. The result was too slow and unresponsive. We also faced challenges with Apple's security disallowing microphone usage in Safari after an iOS update. As a result, we tried to port the game over to Unity for the same reasons, but found the speech system to be incompatible at the time. At the time, there was also no support for streaming audio from microphones from both iOS and Android devices in Unity. After this setback, native Apple development restarted.

Children with cleft play-tested one of the four prototypes implemented in Swift, but found it mostly unusable due to an overly critical recognition system. While speech system improvements were underway, I ran fast 20-minute cascading PD sessions with children with cleft. These sessions featured design probes and medium fidelity prototyping in Adobe XD, discussed in Section 4.5.

After improvements to the speech system were made and the inclusion of a second online system that is used in tandem, as discussed in Section 4.6, all prototype games were implemented. Each new implementation of a mini game included updates that would benefit previously made mini games. Each mini game had unique interaction paradigms that focused on a specific type of speech therapy. This feature became unsustainable to maintain, as the prototypes were useful for evaluation, but not for a unified game experience. As a result, I created a universal SpokeIt framework that unified a singular speech interaction mechanic across all mini games. This interaction design was only made possible through learning what did and did not work in all of the preceding prototypes. The new framework featured the ability to override both speech systems using a game controller for new play potentials and to keep the human in the loop discussed in Section 4.6.1.1. The SpokeIt framework provides an abstraction necessary to update all mini games at once with each new addition or change. The framework also improved the lip sync animation system, closed captions, and universal dictionary preferences. The new framework fundamentally changed how each mini game would work and be implemented. This prompted a major design update to all mini games with new art.

4.3 Proof of Concept

In this section, I describe key implementation details of the underlying mobile, offline, real-time, critical speech recognition system. I present the designs of two articulation therapy game prototypes that culminated in the creation of SpokeIt. I share results from our comparative within-subject study, which included 5 adults with disabilities co-occurring with speech impairment, who played each of the three designs. Finally, I discuss lessons learned about these designs. While children born with a cleft were written into our grant, at this point in the research, I did not commit to focusing only on that population—I was interested in SpokeIt's usefulness in adult populations as well. SpokeIt shows promise for more populations but it was not until later in the research that I decided to reframe [18] the research scope to focus only on children with a cleft. Therefore, I share some background about these populations next.

4.3.1 Articulation and Disability

Adults with developmental disabilities co-occurring with speech impairment may benefit from speech therapy [209]. There is a trend towards helping children with speech impairments [208, 216, 218, 219], but adults with speech impairments may also benefit from support [206, 212]. This support can come in the form of a speech recognition system, discussed below.

Autism spectrum disorder (ASD) is one of the most common developmental disabilities, affecting approximately 400,000 individuals in the United States [220]. A follow-up study was conducted on children with ASD and communication problems when they reached early adulthood showing that the group continued to show significant stereotyped behavior patterns, problems in relationships and with employment, and lack of independence [221]. A person with ASD may have monotonic (machine-like) intonation, deficits in pitch, vocal quality, volume, and articulation distortion errors [206].

A person with cerebral palsy and dysarthria (difficult or unclear articulation of speech that is otherwise linguistically normal) may include anterior lingual place (front of the tongue) inaccuracy, reduced precision of fricative (consonant requiring breath through a small opening) and affricative (Plosive followed by fricative sound like j as in jam) manners, slowness of speech, and indistinctness of speech [207, 222, 223].

Many people with Down syndrome have muscle hypotonia [208]. Muscle hypotonia may cause abnormal movement of the cheek, lips, and tongue, resulting in articulation errors. People with Down syndrome may also speak at a fast and fluctuating rate [224] known as cluttering [225].

Each of the aforementioned developmental disabilities have one general symptom in common—an articulation disorder. For this reason, I focused on the development of a critical speech recognition system capable of distinguishing between correct and incorrect pronunciations. We discuss these implementation details thoroughly in section 4.3.2 below. There are many more technologies that focus on improving speech skills such as fluency, pitch, rhythm, dialect, and aphasia [23, 214, 218, 219, 226, 227], but we did not focus on these.

4.3.2 Creating a Novel Speech Mechanic

Work began with semi-structured interviews with medical speech experts. I asked what technology was currently used for speech therapy, what benefits and drawbacks they anticipated in the use of technology for speech therapy, and what functionality must exist for the approach to be successful. The only technology our experts reported using during speech therapy sessions were iPads displaying images of speech targets for diagnostic purposes. Experts suspected that their patients were having little to no practice outside of the office, even though they recommended 10 minutes of daily practice. They were hopeful that a speech therapy game would motivate their patients to practice outside of the office. Importantly, the experts also stipulated that the system must critically listen to pronunciation and were somewhat concerned that a speech therapy game could condition bad speech practices if its capacity for recognition was poor. The inclusion of correct speech examples mitigated these concerns. Finally, they expressed concerns that many of their patients from lower socio-economic statuses may not have access to the internet, so our game must be functional offline. We budgeted for iPads in our grant so that these populations can keep the iPads with the software installed after the development and evaluation of SpokeIt has ended. We chose iPads because they are categorized as medical devices by the United States Government.

While there are many novel and interesting mobile applications available that can improve the speech therapy experience, we found none that provided a critical speech recognition system in a game for on-the-go or at-home use. Before developing any game prototypes, it was necessary to ensure that it was feasible to listen for both correct and incorrect speech. Many speech recognition systems exist today such as those used in personal assistants like Cortana, Siri, Google Assistant, and Amazon Alexa. We chose not to use these services for multiple reasons:

- We needed a solution that is offline because we are dealing with sensitive speech data. In addition, not every home has access to the internet. Also, online speech recognition systems often have lag and usage caps that would hinder real-time game play.
- Digital assistants like the ones listed above are designed to best-guess speech, not listen to it critically. We needed to be able to fine-tune the recognition to listen for incorrect speech as well as correct utterances.
- We did not want to discard the possibility of using and recognizing non-existent words. Having the freedom to play with silly nonsensical words is a tactic many SLPs use to target specific sound production.

With these requirements in mind, we began searching online for mobile speech recognition libraries that are highly customizable and do not require an internet connection. The library we chose is Pocketsphinx, an offline speech recognition system for handheld devices developed by researchers from Carnegie Mellon [228]. A speech therapy game must be able to listen to speech critically so that the intervention will promote correct speech. Pocketsphinx uses customizable dictionaries that allow developers to customize the targets that can be recognized [228]. The dictionaries that Pocketsphinx employs use ARPAbet, a set of phonetic transcription codes, to map speech sounds to English words [229]. ARPAbet can be used to construct any sequence of phonetic sounds into a word—even words that do not exist. Any set of sounds that an English speaker can produce can be mapped to an ARPAbet representation. We can make new "words" that map to common mispronunciations of correct words. Providing both correct ARPAbet codes and ARPAbet codes that represent mispronunciations give us the power to distinguish between correct and incorrect speech. Table 4.2 shows ARPAbet codes that represent both correct and incorrect ways to say the word balloon.

Pocketsphinx uses acoustic models to map sound data to targets in the dictionary. These acoustic models are hot-swappable and can be altered for better accuracy [228]. This feature creates the potential to alter acoustic models for specific populations, allowing a more accurate model that can listen to adults with developmental disabilities, or even one specifically for children with cleft speech. OpenEars is a free open-source framework that brings the power of Pocketsphinx to iOS devices in native objective-c language for speed and reliability. RapidEars is a paid plugin for OpenEars that gives Pocketsphinx the ability to listen to speech in real time, which is important for a responsive game. The ability to customize acoustic models, to customize dictionaries, to run offline, and to listen in real time motivated our choice to use RapidEars for our speech therapy game prototypes.

Common pronunciations of "Balloon"	**ARPAbet Code**
Balloon	B AH L UW N
Walloon	W AH L UW N
Walloo	W AH L UW
Bawoon	B AH UW N
Balloo	B AH L UW
Bawoo	B AH UW
Alloon	AH L UW N
Loon	L UW N

TABLE 4.2: Pronunciations of the word "Balloon" including correct pronunciation (first) followed by common miss-pronunciations and their corresponding ARPAbet Code

4.3.3 Prototypes

The first two prototypes were designed by Rubin as part of their doctoral research [217, 230, 231]. I then took over the NSF project and started working on the third prototype, SpokeIt, included in our initial proof of concept. During this transition, I conducted the following within-subject comparative study on the three prototypes with five adults with developmental disabilities co-occurring with speech impairment, detailed in Section 4.3.4. We were concerned with participants' interest in using a speech therapy game to improve their speech, their opinion on each of the three prototypes, their preferred game structure, and relevant reward systems they would be interested in.

4.3.3.1 Speech Adventure

FIGURE 4.1: Speech Adventure cabin scene where player must help Sam the Slug get dressed before going outside

The first prototype that was developed was Speech Adventure [217, 230]. Speech Adventure, shown in Figure 4.1, is a storybook-style game that employs an off-screen narrator to give directives on how to help Sam the Slug complete tasks. Visual cues in the form of glowing blue outlines inform players which parts of the scene can be interacted with and touched. Once touched, the corresponding target phrase is announced by the off-screen narrator.

To make progress in the game, the player must repeat the target phrase that was just announced. The target words are displayed at the bottom of the screen and are tightly tied to the speech recognition system. Words turn green as they are said correctly. To make progress, all words must be green. Words can be said out of order and words that were missed anywhere in the phrase can be repeated.

The green ear in the upper left corner of the screen indicates that the system is actively listening. When the off-screen narrator is speaking, the green ear turns white to signal that the system is not listening. We found it important to suspend recognition during these moments so that the in-game audio does not trigger game events.

The story of Speech Adventure starts with dressing Sam in boots and a hat. Once Sam is dressed, the player must say "Open the door" to journey outside. Once outside, the player must pop three balloons that are blocking a bridge by saying "Pop a balloon" before continuing on the journey. These phrases were provided by SLPs.

A challenging design aspect of this game was that each target phrase had to be carefully crafted to fit into the narrative of the game. Development of new scenes that incorporated target words proved to be very time consuming, which could result in minimal content. We worried that Speech Adventure would lose its novelty after a first play-through. From conversations with the SLP, we realized re-playability was an important feature for a game that should be played for 10 minutes per day.

The majority of the allotted 10 minutes of daily practice should be spent producing target words and practicing speech. Yet, the narrative nature of our storybook-style design limited the number of utterances that could be produced in 10 minutes, which then caused concerns within the design team about the therapeutic value of our game.

The nature of handcrafted narratives limited our ability to dynamically swap target words. According to a SLP we interviewed, a speech therapy game would benefit from the ability to customize targets dynamically based on the types of speech therapy each individual player needs.

Although preliminary play tests indicated that players love the storybook-style Speech Adventure game [217], the considerations above prompted us to rethink how a speech therapy game should be structured.

4.3.3.2 Speech with Sam

To maximize the number of target words produced in a 10-minute period, we hypothesized that single-word utterances that had an immediate effect on gameplay would yield more speaking time. Removing narrative between utterances reduces the amount of time during which the recognition system is suspended. This resulted in the development of Speech with Sam, a series of speech-controlled mini-games, shown in Figure 4.2. The mini-game structure allowed quicker development time, which yielded more content to play. Because targets are not directly linked to a narrative, implementing a diverse range of dynamic targets would be more feasible.

FIGURE 4.2: Speech with Sam rocket mini-game where rockets are set off by saying the appropriate target

Speech with Sam features a series of mini-games ordered randomly for a specified amount of time. In the rocket mini-game example above, the player must tap one of the three rockets. Touching a rocket reveals an in-game prompt that specifies a rocket's trigger word. Once the trigger word is said, the rocket blasts off the screen and is replaced by a new rocket with a new random trigger word.

For every rocket launched, the player score is increased by 1 and displayed in the green rounded rectangle in the upper-left corner of the display. This score is recorded at the end of every mini-game to keep a record of high scores and to track player score trends.

The number in the blue rounded rectangle, next to the score, is a countdown timer until the next mini-game is played. After the timer reaches 0, the score is recorded, and the player is presented with a different randomly chosen mini-game. All mini-games run for a standard amount of time. It is possible for players to play the same mini-game in one session, but not twice in a row.

The green ear in the upper-right corner of the screen works in an identical manner to Speech Adventure in that when it is green, the speech system is listening, and when white, the speech system is suspended so that in-game audio does not trigger events. The written prompt was moved to the top to join the other heads up display elements. When players say the target word, the text turns green and the game immediately responds. In Speech Adventure, targets were often multi-word phrases, whereas in Speech with Sam, the targets are single words.

In a preliminary study [217], we found that Speech with Sam was successful in increasing the words per minute from participants, meaning Speech with Sam has the potential to be a more effective speech therapy solution. In that same study, we found that participants were unenthusiastic when presented with a mini-game they had played before. Our hypothesis about mini-game re-playability being high was not necessarily true.

4.3.3.3 SpokeIt Alpha

SpokeIt, shown in Figure 4.3, is a storybook-style mini-game hybrid. By adding a story around the mini-games that fit into an overarching plot, we have the potential to both produce a high output of words per minute and keep users engaged.

SpokeIt is the first speech therapy game to both demonstrate correct pronunciation with pre-recorded audio and lip animations. One of the medical experts we interviewed later suggested that showing correct speech is important as well as hearing correct speech. We did not want to break immersion by displaying a realistic mouth in an animated 2D environment. I found a solution that allowed us to sync the audio that exemplified correct speech with animated mouth transitions on our characters. The lip animation effects were achieved using Adobe Character Animator. Each phoneme mouth shape was crafted in Adobe Photoshop with three frames per transition, resulting in smooth transitions between mouth shapes. Adobe Character Animator's Lip Sync feature and our frame transitions

FIGURE 4.3: SpokeIt card coloring mini-game

automatically map our voice actor's speech performances to the appropriate mouth shapes. The motivation behind this work is to give players visual cues on how a word is said. Adobe Character Animator's abilities to synchronize lip animations and replicate actors' facial expressions is shown in Figure 4.4.

The SpokeIt prototype, shown in Figure 4.3, is meant to blend the positive aspects of the Speech Adventure and Speech with Sam experiences. Therefore, the beginning of the game starts with a narration from Sam the Slug and their desires to go and visit a close friend. To get to the friend, the player must partake on a long journey filled with new experiences and challenges. In the example above, Sam meets a friendly creature named Red who is struggling to learn colors that start with the letter "B"—or in the future, colors that start with any letter the player needs to practice. Sam knows the player is great with colors and asks them to teach Red colors that start with "B" by saying the color on numbered cards.

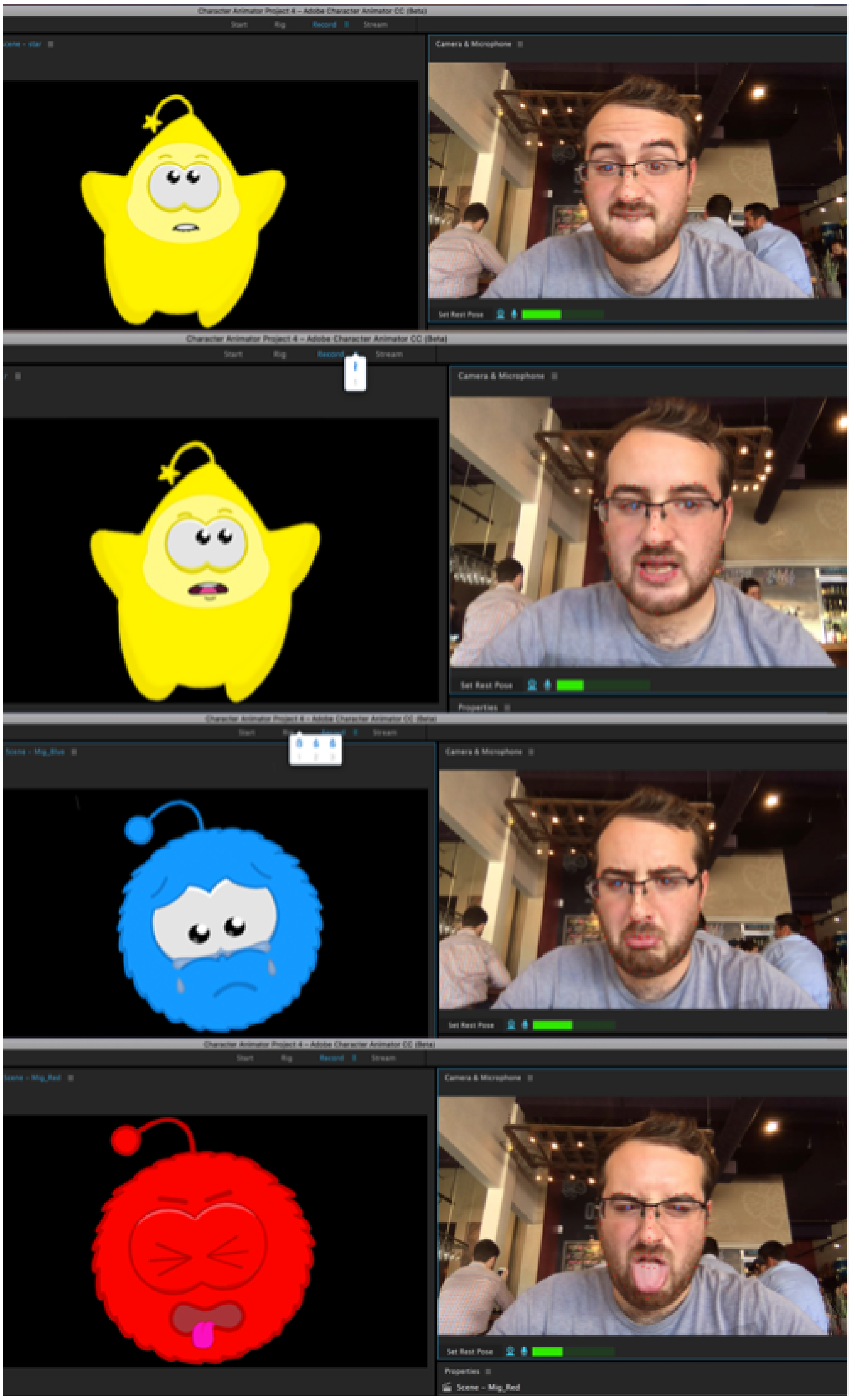


FIGURE 4.4: Top: Character demonstrating /V/ sound, 2nd from Top: Character demonstrating /L/ Sound, Bottom: Characters showing sad and disgusted expressions

Unlike Speech with Sam and Speech Adventure, an on-screen character narrates the game. SpokeIt is the first prototype to include completely animated characters with mouth transitions. Unlike Speech with Sam, but similar to Speech Adventure, SpokeIt demonstrates how each target should be pronounced. SpokeIt is the only prototype that automatically moves on if a player is struggling for over 10 seconds.

Instead of words lighting up green as they are spoken correctly, SpokeIt uses a "Heard" element that displays exactly what speech was recognized—correct pronunciations and incorrect pronunciations. The target word or phrase is displayed in the upper-left corner of the screen. SpokeIt has word, phrase, and sentence targets. The ear in the upper-right is crossed out when the system pauses.

Unlike both predecessors, SpokeIt is completely touch-free. To simplify game directives and required interactions, the only form of input that makes progress in the game is speech. We use the touch-screen to aid players. When an element is tapped, Sam says that word aloud to help players know their targets, which is important to players who cannot read.

4.3.4 Prototype Comparison Study

Prototype	**Game Style**	**Instruction**
Speech Adventure	Storybook	Off-Screen Narrator
Speech with Sam	Minigames	Text prompts
SpokeIt	Hybrid	Main character

Table 4.3: Key characteristics of each prototype

Table 4.3 summarizes some key differences between the three prototypes we developed, namely the game structure style and how the players are prompted on game targets. We hypothesized players would enjoy the hybrid, mini-game, storybook style that SpokeIt provides because it includes fast-paced gameplay surrounded by narrative. We also hypothesized a main character who demonstrates speech with mouth animations would increase usability and therapeutic value.

After development of the third prototype had been completed, researchers wanted to ensure progress on the design was moving in the correct direction. We wanted to ensure our game was usable and learn what future features or rewards would keep players engaged.

4.3.4.1 Protocol

We began by administering a preliminary survey to collect demographics, interest in speech therapy games, and general game use. We then conducted a within-subject comparative study where each participant played each of the three prototypes in a random order. Researchers were present to facilitate, answer questions, and change prototypes when necessary. Following the preliminary survey, an interview was conducted, where we collected rankings of each of the designs, usability feedback, and core mechanics feedback, asking a mixed set of targeted questions to explore positive and negative characteristics from each of the three prototypes. We also discussed the kinds of reward systems our participants would be interested in. Each participant was asked the same set of questions. Facilitators wrote down answers to each of these questions and also jotted down any quotes or observations they had. Our study was video recorded. We concluded the study with a 3-question 5-point Likert survey to receive feedback on how well-received our speech recognition system and speech mechanics were. We were interested in its perceived accuracy, responsiveness, and mechanics. Participants were asked if 1) the game accurately heard them, 2) The game responded quickly to speech, and 3) They would want to play at home.

4.3.4.2 Participants

Our research lab has an on-going relationship with a local day program for adults with developmental disabilities. We asked the program staff to provide us with

Participant	**Age**	**Sex**	**Game Play Frequency**
P1	27	Male	5 Days/Week
P2	31	Female	2 Days/Week
P3	24	Male	7 Days/Week
P4		Male	7 Days/Week
P5		Male	2 Days/Week

Table 4.4: Participant Demographics

facilities to conduct our study and to provide us with participants with speech impairments who are legally able to provide consent. Regarding the demographic information collected, all individuals who attend this day program are adults. Two participants were not comfortable sharing their age but seemed to be similar in age to the other participants. Table 4.4 below outlines the basic demographic information of our five participants. One participant had cerebral palsy, one had Down syndrome, one had ASD, and two were diagnosed with mental retardation co-occurring with articulation disorders.

4.3.4.3 Facility

We were allowed to use two medium rooms. Because neither of the two rooms was big enough to accommodate the entire group and we had to work within the daily schedule, we split participants between the two rooms to run the study in parallel with all participants. The situation was not ideal, but to remove as much bias as possible, we asked each question to each individual in a random order. For example, Participant 3 might answer question 1 first, then Participant 2, but Participant 1 answered question 2 first followed by Participant 3. Each participant had the opportunity to answer each question before the group moved on to the next question. The facility was also not ideal for the within-subject play of the games. The speech recognition works best in a quiet environment, but this was not possible given the constraints of our facility.

4.3.4.4 Equipment

We brought enough iPads for each participant and a few extra in case of technical problems, two laptops with webcams to record each of the rooms, surveys, scripts, consent forms, and note-taking materials.

4.3.5 Results

We used handwritten notes from researchers containing participants' responses to questions about relevant reward systems and opinions on each of the three prototypes. We used the results of our 3-question Likert survey and participant quotes about the speech recognition to report insights about its use. We used video recordings of the participants playing our three game prototypes to identify usability issues, and player reactions. For our analysis, two researchers created codes and themes while three independent coders analyzed all videos for our qualitative analysis. We use BORIS to analyze the videos using our codes and themes. Three researchers independently analyzed all videos using our BORIS file. The emerging insights include preferred game styles, reward systems, and usability concerns. All participants play games two or more times per week and would be interested in using games to improve their speech. Participants reported that the games they play most commonly are car games, racing games, solitaire, bowling, and NFL sports games. Participants reported that they have difficulty speaking aloud, have fluency difficulties, and are sometimes unsure of what to say when speaking. In the following sections, we organize our findings by the specific prototype they relate to. We then report general insights into reward systems that our participants were interested in and their experience using the speech mechanics.

4.3.5.1 Speech with Sam

Researchers observed that two participants were laughing while playing Speech with Sam. This may be because of humorous phrases that are present in the narrative such as, “Slugs don’t wear boots!” Due to software updates, some features of the game became unresponsive, which understandably frustrated some of our players. It was not always obvious to the players that they needed to touch flashing objects to progress in the game. All instructions in the game were displayed as text, but many of our participants could not read, so researchers aided players by dictating the instructions. Players wanted better feedback when interacting because at times, they were unsure if the game accepted or rejected their responses. They were also unsure when they had to repeat themselves. Participants enjoyed the pace of Speech with Sam.

4.3.5.2 Speech Adventure

The mini-games in speech adventure, particularly in the rocket scene, gave immediate feedback when the player correctly interacted with the game. Most players’ visceral reactions to the sounds and animations were very positive. They enjoyed the satisfying pop sound of fireworks that celebrated their success. Speech Adventure kept track of player scores and displayed them to the participants. Two players reported that seeing their score was satisfying and helped to track their progress. Players who could not read also struggled with this prototype because the instructions were written out as text and needed the researcher’s help to navigate through the game objectives. Many of the mini-games rely on the players to speak in the correct rhythm, but this was extremely challenging for some. The scenes automatically progress after an allotted amount of time. Players found that this happened too fast—just as they were beginning to understand the objectives and mechanics, the next game would be displayed. Some of the game objectives were too complicated and several players never learned how to complete objectives within the allotted time. In general, Speech Adventure needs to be slowed down drastically and the instructions need to be clearer.

4.3.5.3 SpokeIt Alpha

Three out of five participants preferred SpokeIt to the other prototypes. They especially appreciated that all the instructions were spoken aloud by the main character and displayed as text on the screen. Participants found the interaction objectives much simpler because SpokeIt never requires a player to touch the screen. Most participants also found SpokeIt to be incredibly aesthetically pleasing. They loved the colors, graphics, and animations. Participants preferred the highly animated main character in SpokeIt because it represented a more responsive and lively element. One participant was very interested in bringing SpokeIt home with her. Another participant commented that he would like SpokeIt to repeat the instructions because he did not always remember what he was supposed to say. Most users seemed enthusiastic about playing SpokeIt again, indicating that the hybrid structure may improve re-playability of mini-games because they fit within an overall narrative.

4.3.5.4 Speech Recognition and Mechanics

		Likert Results	
	Q1	Q2	Q3
Values	4	4	4
	4	4	4
	5	4	5
	2	4	4
	2	4	4
Average	3.2	4	4.2

TABLE 4.5: Speech Recognition and Speech Mechanics Likert Survey Results

We report that users are neutral about the accuracy of our speech recognition system (Q1), but found it responded quickly (Q2). They found the speech mechanic to be rewarding and enjoyable, and they considered the games suitable systems to promote practicing speech at home (Q3). These values can be seen in Table 4.5

4.3.5.5 Rewards

We are interested in rewarding players for practicing speech in a meaningful way to them. Hence, we brainstormed a few ideas with our participants and asked them to vote on which reward would be most interesting to them. Our ideas included:

- Hats and clothes to accessorize a character or avatar after completing sessions
- Having scored points to spend in virtual store. Points could be spent to buy items for a virtual garden or furnishing the character's house.
- Reducing total time needed to practice speech in the future. If a player does really well in a 10-minute session, then tomorrow they only need to play for 8 minutes.
- Out-of-game rewards (Stickers, candy, other physical reward)

Overwhelmingly, our participants were interested in out-of-game rewards. They were extremely excited about the idea of receiving candy when they do well in the game.

4.3.5.6 Usability Considerations

Watching players use our systems was very informative. We identified three main issues that must be addressed in speech therapy systems:

- Many participants cannot read: the game must be very clear and be designed to accommodate players that cannot read. Objectives should be spoken aloud and be repeated if necessary. If participants are struggling, the game should either change the objectives or move forward with the plot.

- To make progress in the game, players must use their speech. Touch should be used to support players, provide clues, or demonstrate correct pronunciation. These mechanics should not be mixed.

- More feedback for correct and incorrect interactions must be given to make progress clear. If the player pronounces a target incorrectly, the game should support that player in saying it correctly.

- Many users put the iPads to their heads because they had trouble hearing—the game volume must be louder, or headphones must be provided, especially in noisy environments.

4.3.5.7 Structure

We found that players prefer the hybrid structure because mini-games were given context in an overarching plot. Mini-games that are played out of a narrative context seem to lose their novelty as soon as they are repeated. Our users seemed to care a lot about aesthetics and animations indicating that high levels of polish are important. Storybook-style games require much more work to generate content and narrative consistency. Speech therapy games should be available and fresh for as long as the individual needs to practice speech. Narrative content that surrounds mini-games is an effective balance of development time, re-playability, and diversity of speech targets.

4.3.5.8 Methodological Challenges

Our users struggled with Likert style questions, so we needed to adapt how we conducted them onsite, which we detail here. This finding may be informative to other researchers working with a similar target group (adults with developmental disabilities). We first asked whether they agreed with the statement, disagreed with the statement, or did not know. If they did not know, we marked down a 3. If they said they agreed, we asked if they agreed a lot or a little. If they said they agreed a lot, we put a rating of 5. If they said they agreed a little, we marked down a 4. We followed the same process if they disagreed. If facilitators felt a participant was answering just to please us, we would ask the same questions in the opposite way and remind users that we want them to be authentic. Some participants changed their answers, which led us to believe our results may not be completely representative of our population. Asking Likert-style questions in this way was cumbersome and may result in data that does not represent the population.

4.4 Initial Participatory Design

Following the participatory process defined in the Methods chapter in Section 3.2.2, I integrated the feedback from the study above and collaborated with adults with developmental disabilities co-occurring with speech impairments on new designs for SpokeIt minigames that would later be made to fit within the overarching narrative.

FIGURE 4.5: Users at HOPE Services Prototyping on Paper

4.4.1 Build Bridges

Our research lab has a long-standing relationship with HOPE Services, a day program for individuals with developmental disabilities. To build this bridge, many members of our research lab volunteered at the center to learn more about the clients and build a good rapport with the staff. With HOPE Services visiting our lab every two weeks over the span of a year, we created a number of assistive technologies such as virtual reality therapy experiences for adults with disabilities [94, 96]. After participating in many studies, HOPE services found the relationship to be mutually beneficial because they saw the potential benefits that the projects offer for their clients. Another benefit is that HOPE Services can document the sessions as community outreach, which is helpful in finding funding and receiving hardware such as VR systems.For this project, HOPE Services partnered us with individuals that fit our target population (Figure 4.5)—people who were interested in improving their speech. We collaborated with 15 participants who wanted to improve their speech and had developmental disabilities such as cerebral palsy, Down syndrome, and autistic spectrum disorder. We had 5 female and 10 male participants. Their ages ranged from 21 to 58 years with an average age of 33 years.

4.4.2 Develop User Model

To develop a user model, we collected basic information: demographic data and information about their disabilities and any accommodations we would need to provide. For example, in this session, we had one participant who was unable to write due to an injury, so a staff member assisted her when she needed to draw or write. Further, not all participants could read, so all written materials were read out loud. From previous studies, we knew the clients at HOPE Services thrive in focus groups where they can collaborate and build diverging ideas off of one another. In our experience, having a flexible attitude usually yields successful sessions and we know that some traditional methodologies, such as Likert questions, surveys, and cognitively demanding methods are difficult to implement so we avoid using them in the design of our PD session [192].

4.4.3 Map Possibilities

At the start of the session, we introduced participants to the project by asking them three questions:

1. Are you interested in becoming game designers for the day?
2. Have you ever had a difficult time communicating?
3. Are you interested in designing a game that helps you work on your speech skills?

At this point, the participants were eager to get started—one even exclaimed "a game like this would help me a lot because people don't always understand me." We leveraged this forward momentum in the next critical step—providing context and the goals of the session. We played the opening cinematic of the game to introduce participants to the SpokeIt storyline and universe. Using Adobe Character Animator, we demonstrated how we bring our characters to life by using webcam tracking, speech-to-lip animations, and premade emotion animations, shown in Figure 4.4. We let participants sit in front of the webcam and control each of the Migs, which immediately elicited overwhelming excitement from the participants, who had comments like "I want to be a game designer now!" and "Wow! That's so cool!" Once the participants understood the plot and characters, we introduced the goals of the session—to design fast-paced minigames that target a specific aspect of speech therapy and fit into the overarching plot. We began by asking participants to write down a specific aspect of speech therapy they would like to design for such as articulation, rhythm, or loudness. Before getting started, we posed one last design challenge—that the minigames had to use speech as the only input mechanism. This forced participants to think well about the speech mechanic—which also yields mini games that are accessible to those with motor impairments.

4.4.4 Develop Prototypes

We let participants start prototyping in low fidelity using writing utensils, markers, paper, and props. The props we brought included a microphone, pipe cleaners, foam paper, and other various items from the Dollar Store. All participants chose to use paper and writing utensils instead of using props. This prompted us to think about the types of props and tangibles that might improve the next session, which we discuss in the "Participatory Design with Children" section, Section 4.5. Some participants chose to write their ideas out, while most drew pictures.

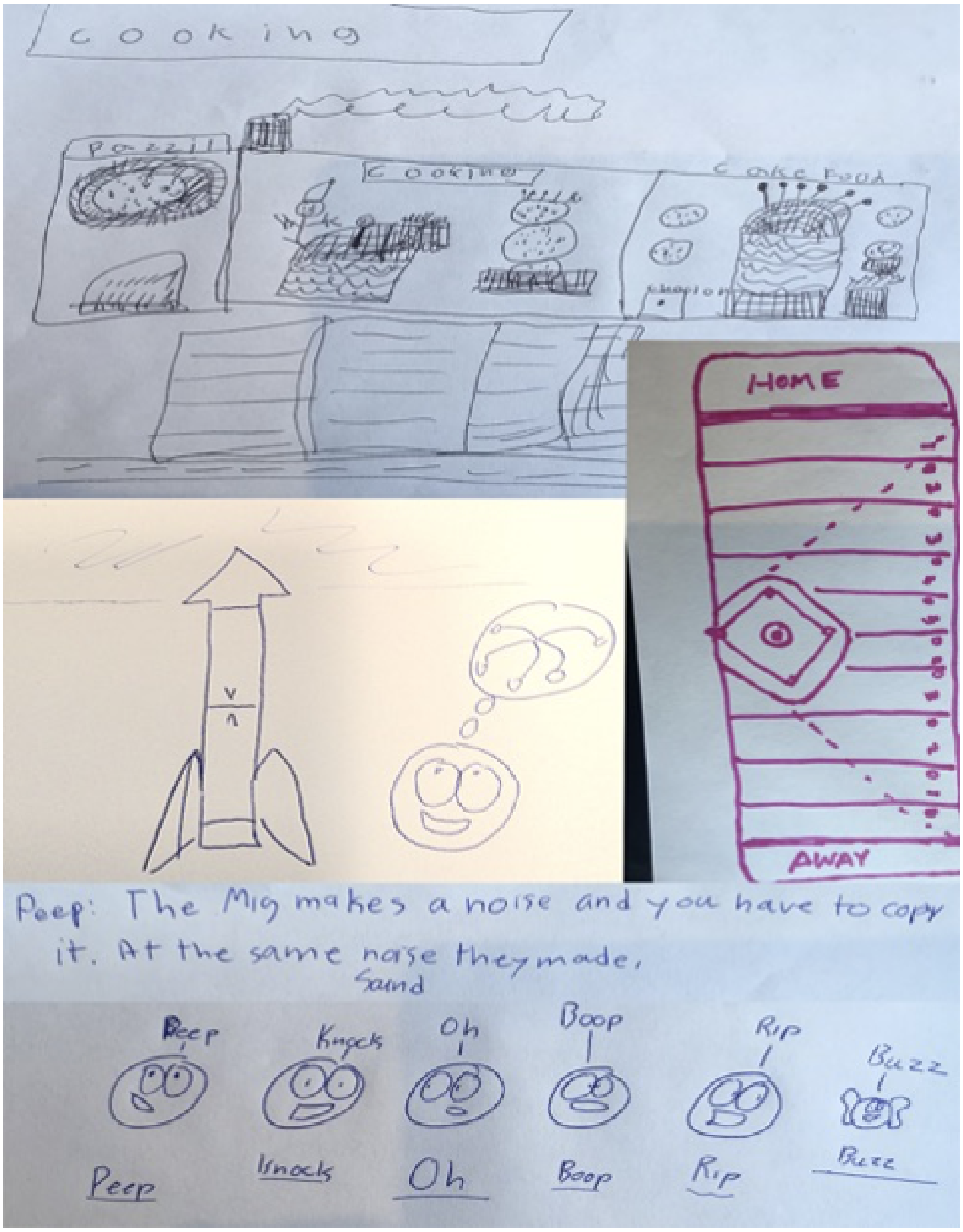


Figure 4.6: Paper Prototypes

We gave participants 20 minutes to design as many games as they wanted to. During the 20 minutes, staff and researchers answered all participants' questions and rotated around the room having one-on-one meetings with them. Having plenty of research assistants and staff made the one-on-one meetings with each of the 15 participants possible. During these meetings, we would ask the participants to explain what their game was, what effect correct and incorrect speech had on the design, what type of speech therapy it was targeting, and how it incorporated the plot and characters. These questions challenged participants to think about all the necessary components of the design. Some of their designs are shown in Figure 4.6.

4.4.5 Elicit and Integrate Feedback

Inspired by the Delphi Method [232], we came together as a group and each participant presented their ideas. After each idea was presented, we provided the opportunity for the rest of the group to comment and add on to the ideas. As ideas were presented and discussed, researchers who were sufficiently familiar with the technology to quickly create digital mind maps documented everything the participants presented in a mind map template, which was projected on a screen visible to everyone. A picture of the participant's paper prototype with a title served as the center of the mind map. The "Spokes" of the mind map were generally "Premise (basic description)", "Speech Mechanic", "Plot", "Characters", "Win Condition", and "Loose Condition". The "Speech Mechanic" spoke was broken into subcategories: "Correct Speech Events" and "Incorrect Speech Events." After each participant presented their idea, and before opening up for discussion, researchers asked the participant what belongs in each empty "Spoke" that was not covered in their presentation. We did not move on to another design until all of the "Spokes" were filled out. The mind map provided all the information needed to describe a minigame: the plot, the goals, the interactions, the effects of the interactions, and how to win/lose the minigame. We kept the mind maps during the lunch break to further prepare for the rapid prototyping session described later. At this point in the session, almost half of our time was up, and we wanted to make sure we knew the participants' favorite ideas so that we could prototype those first. The number of votes were important when ranking the favorites. Each participant was asked to vote for their top two games. The first choice was given two points and the second choice was allotted one point.

4.4.6 Continue the Iteration

Participants came back from lunch break and co-created their minigames with us using Adobe Experience Design. Before visiting Hope Services, a great deal of time was spent preparing templates and assets within Adobe Experience Design to ensure the rapid prototyping would run smoothly. Common screen layouts, game elements, and character images were always in sight. SpokeIt has an image asset library with thousands of pictures of background assets and characters. These assets use a descriptive naming convention that makes it easy to quickly query for the types of images requested. For example, we could search for "Blue Mig Fear" or "Jungle Tree 1" and quickly grab that image for use in Adobe XD. Many of these images came from Glitch the Game, and were therefore in the public domain. On a separate desktop, we had a Google Images tab open and set to search for images labeled for reuse. Any assets that we did not have, we were likely to find on Google without worrying about infringement because of the "labeled for reuse" setting. There were a few instances discussed below where we did not have an asset and we could not find one on Google Images. In these cases, we projected an iPad Pro on the screen running Adobe Draw and quickly sketched the asset to the participants' specifications until they were satisfied.

FIGURE 4.7: Digital Prototypes

For each game, participants shared how they envisioned the level to look through open discussion and their sketches. Designers added backgrounds, characters, props, and design elements to the screen almost in real time. In cases where participants disagreed on which image was best, the group would vote, but this rarely happened. Participants then dictated how the scenes should look, where characters should be placed, and what prompts each game would display. Multiple screens of each minigame were designed to communicate the flow of the game events, state changes, and prompt changes, as shown in Figure 3. Once participants were satisfied that all interactions were accounted for, we would move to the next prototype. A benefit of using Adobe Experience Design is that scenes can be connected by event triggers and demonstrated live on an iPad. Participants could immediately see how game events would be connected and experience a medium fidelity prototype of the minigames they designed earlier that morning. We could specify hotspots on the screen that correlate to correct and incorrect speech when touched. This allowed us to use Wizard-of-Oz techniques to demonstrate how the speech recognition system would respond.

As we worked in Adobe Experience Design, participants saw their creations come into fruition in almost real-time. They would say things like "The Blue Mig needs to be a bass player!", "The yellow one doesn't belong there!", and "I think we should use red to represent not throwing the ball very far." After an interaction was completed, a duplicate screen would be created, tweaked, and a trigger event set to exemplify different game events and interactions. Once participants felt a minigame prototype was finished, we would run it on an iPad or computer to test it out and elicit feedback. We used Wizard of Oz [233] to test the storyboards by asking participants to complete the game activities to progress in the storyboard—researchers served as the speech recognition system. The individual who first imagined the idea had the role of player for each minigame, while the others critiqued the designs and gave feedback. We managed different levels of input from participants by prioritizing those who raised their hand less often and organically asked for feedback from everyone in the group. As a result, none of the participants tried to monopolize the conversation. Once participants were satisfied with all the work they had done, we had them present the minigames to the staff at HOPE Services. By having the participants present their designs and describe their games, we could understand, from their perspectives, what the most important features were, what they understood the interactions to be like and when they were triggered, and it gave them pride and ownership over their work. The HOPE Services staff, including the director, were extremely impressed with the quality of the designs and the creativity of the clients. One of the staff commented "It's really neat how fast you were able to make those screens." The director told the clients at the end of the session "I didn't know you were all so creative! I'm really proud of how well you all behaved."

4.5 Participatory Design with Children

After implementing the minigames from my first participatory session, I pivoted my focus to children born with a cleft because of our NSF grant. I sought out disadvantaged populations, specifically families with low socioeconomic status from the agricultural Central Valley of California, so that they may be better represented in the technology. We visited our collaborators at the UC Davis Medical Center where children with corrected cleft are assessed by different medical experts including speech pathologists, behavioral therapists, plastic surgeons, sleep therapists, dentists, etc. We were invited to take part in a "clinical day" where patients are assigned to a room while a variety of doctors rotate in and out to see each patient. Seven children participated in our study and their ages ranged from 2 years, 7 months to 10 years, 9 months (M = 6 years 1 month, SD = 3 years 6 months). They were accompanied by their parent(s), who observed them play and were also interviewed. We also interviewed two speech language pathologists. In all, we collected data on 7 children, 7 parents, and 2 Speech Language Pathologists. Per request of the speech language pathologist and in order to minimize interference to the doctors' rotations, we designed a participatory design protocol that lasted 10 minutes, which would be conducted during "gaps" where no medical professionals were present in the patient's assigned room. Because our time was so limited, we carefully designed our protocol based on lessons learned from my previous participatory design session described above and by employing the Connected Learning Framework [132], which serves as the formatting for the subsections that follow.

4.5.1 Everything is Interconnected

In order to come up with play scenarios, children were provided with tangible co-design probes, toys, and props (see Figure 4.8). The tangible representations of our characters connected the play session to the SpokeIt Universe. These handcrafted felted characters that I produced were intended to make the design props more connected to the design activity, which is a lesson learned from the previous participatory design session. Additionally, children are natural players and often find toys intuitive. The animal flash cards and word flash cards were chosen because they are rated as developmentally appropriate words for ages 3 years and older. The letter and number magnets were useful random character or number generators. The stickers were a gift to the children for participating. Each of these materials were chosen for strategic reasons.

At the beginning of the session, we played SpokeIt's cinematic on a laptop to remind participants of the story and to help them connect the virtual and tangible characters. Next, children were presented with the rest of the tangible co-design probes to create and play game scenarios. In between sessions, we created medium fidelity prototypes of these play scenarios in Adobe XD. We then had the following participants play and critique the adobe XD prototypes so that each design was tested and iterated with subsequent participants, hence cascading participatory design sessions. This meant valuable design knowledge was not lost to time because it was made immediately after sessions. Each design could be iterated multiple times in the day, with multiple children, in a medium fidelity environment (Adobe XD). Children evaluated other children's designs and this gave insights into which

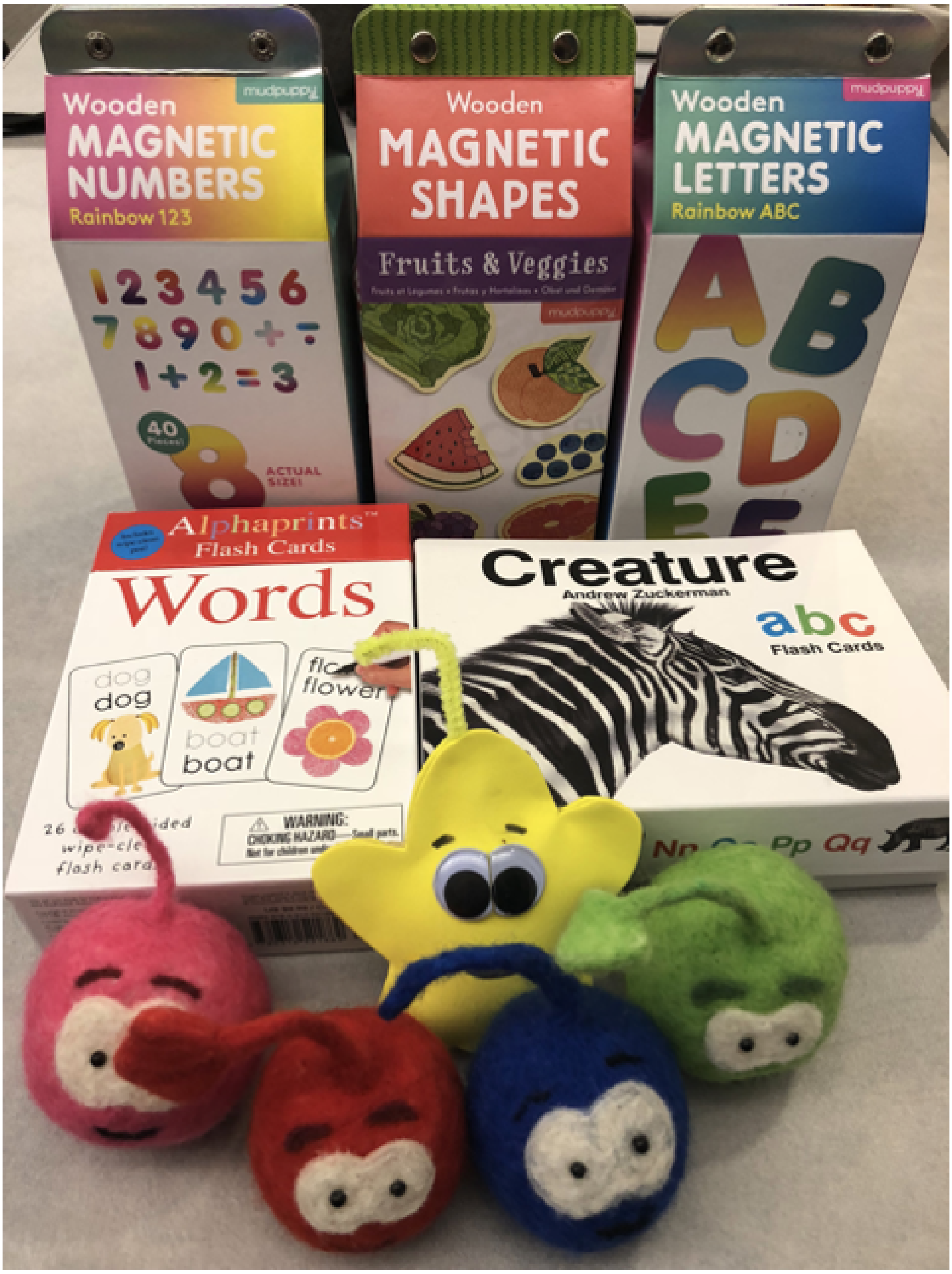


FIGURE 4.8: Tangible design probes used for cascading participatory design sessions

features were important to multiple children versus just the child who made the game.

4.5.2 Learning Happens by Doing

FIGURE 4.9: Child giggling while interacting with the design probes used in the clinical co-creation session

To inspire them, they were asked to first play either a play scenario we had prepared or one that a previous child had proposed. Children were encouraged to iterate these scenarios, by changing the rules or objects used, and then to play the new scenario. For example, if a game required them to repeat a word X number of times, where X is a number magnet pulled from a container, we asked that they actually draw a number and repeat the word that many times.

We found two aspects essential: First, a warm-up scenario is helpful so that children understand what they need to create [234]. Second, having tangible play props was important, so that children had an entry point into the design world. The character props allowed children to immerse themselves in the universe and come up with interesting play scenarios. Children really liked these tangible characters, held onto them, played with them, and felt comfortable using them to make new games.

4.5.3 Challenge is Constant

In the latter cascading co-creation sessions, the children played scenarios that had already been mocked up in Adobe XD. Facilitators presented the iPad with the prototype running and read the written instructions out loud to the children. Using Wizard-of-Oz techniques [233], facilitators took the roll of the speech recognition system and the narrator. They would clarify instructions, give helpful hints, and provide feedback when necessary, as the game would do when it's finished. We took note of when they were engaged, which design elements the child seemed to enjoy the most, and when the child needed more support.

4.5.4 Anyone can Participate

After playing the previously made designs, we invited children to come up with another play scenario using the tangible probes. The facilitator helped the children polish it with questions such as: what happens next? How do they do that? What do they need to say to help? The facilitator reminded players that all of the challenges should require speech. Once the play scenario was concluded, the child played it once or twice with the help of the facilitators. Last, the children were asked general questions about the play scenario, such as: what do you like the most about this game? Why? What do you like the least? Would you like playing this game at home? They were also asked which game of those they had played they liked the most. At the end of the session, the child chose a game character sticker to take home as a souvenir.

Co-creating a game—even if it is a sketch of a play scenario—is challenging, and even more so if your co-creators do not have a background in game design and are children (!). However, children are experts in make-believe and crafting a magic circle comes natural to them. The challenge is crafting the right magic circle—one that can help them in their speech therapy.

4.5.5 Designs

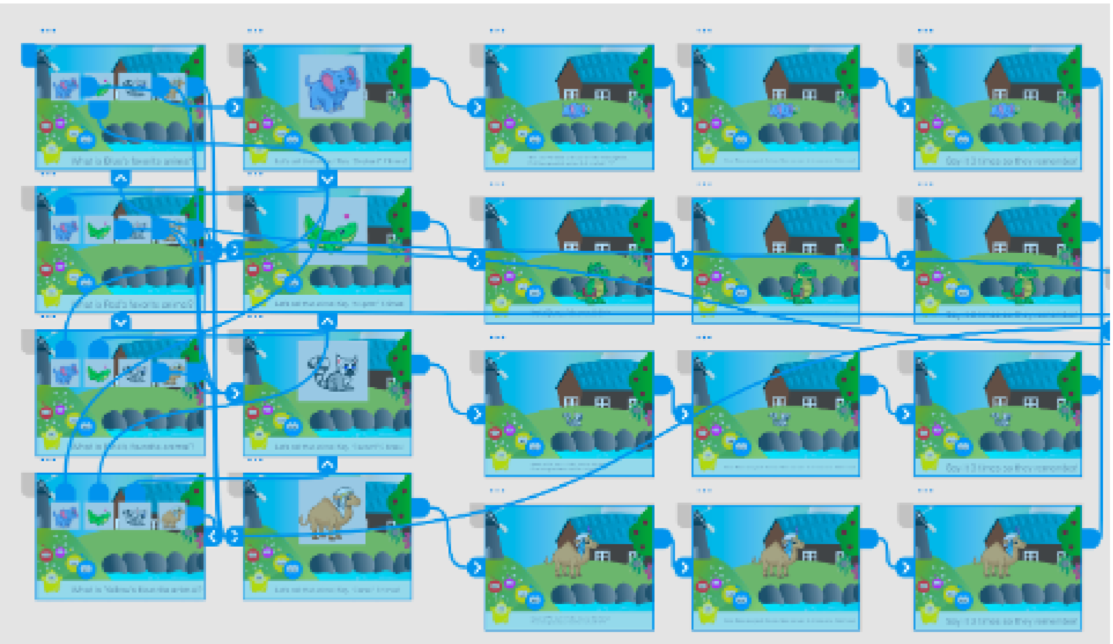


FIGURE 4.10: Adobe XD medium fidelity prototype of farm animals mini-game rapidly developed during gaps. Blue lines illustrate the connections for navigating the prototype

The first design (see Figure 4.11) is a farm-to-table minigame where players cultivate the crops needed to make a salad. In this minigame, players pick the various fruits and vegetables by saying the name of the vegetable. If the salad requires five tomatoes, they would say tomato five times. During the Wizard of Oz Adobe XD playtests, we gained valuable knowledge about how we naturally support children and ideas on how this should be incorporated into the final product. For example, it helps to repeat the same directions worded in different ways. Different children can complete the same challenge with various directions. Silence and numerous incorrect attempts indicate confusion. We found the "magic" number to be three - three seconds of silence or three incorrect attempts in a row indicates the child might need support. If there is a list of items required, it helps to provide example solutions. The game should ask the child if they need help when they might be struggling. Sometimes they just need more time to complete the task or a few more tries. We also found that children enjoy silly, euphonious words like “pickle”, which may be more challenging to guess, but are more rewarding because they are fun to say.

FIGURE 4.11: Adobe XD medium fidelity prototype of gardening mini-game rapidly developed during gaps.

The second design (see Figure 4.10) started as a predesigned scenario to spur creativity, but the children enjoyed playing it and iterating on it, so we decided to mock it up in Adobe XD on the scene. The characters were at a farm with no animals. To bring an animal to the farm, the child needed to say the animal’s name and the sound that the animal makes. To give the animal a name, they needed to say a name that started with the same sound as the type of animal (e.g., Cameron the Camel, Ranger the Raccoon, Ellie the Elephant). At this point, the facilitator asked the child to randomly pick up a number card out of a box. “[X] times!

You need to say their name [X] times so they remember it". When the child calls the [animal] [X] times, that animal's card is turned over. The same process was repeated for the three other animals.

The props directly influenced emerging designs, which is why choosing appropriate props was extremely important. We used wooden magnets to act as random letter and number generators, age-appropriate flash cards to prompt words that need to be spoken, and tangible, felted characters crafted to look like the characters in the game. The props directly influence resulting designs, so if the facilitators are not careful with these choices, the emerging play may be constrained by rules that do not fit goals. It can be challenging to redirect focus and play to the goals of the session. Our probes, particularly the flash cards, helped keep play constrained to using speech. Because children had already played the game, they understood the constraints of the SpokeIt Universe. It helps to clearly define the play space.

4.6 Implementation Details

Based on the previously described participatory design sessions, I had enough material to implement a full version of SpokeIt. The first session inspired the minigames that were implemented, while the second session inspired the core mechanics and support features that were implemented. The framework I developed that provides all of SpokeIt's speech mechanics, support features, and overarching flow is described in Section 4.6.1. The resulting minigames are described in Section 4.6.2. Finally, to support speech therapists, a prototype for a companion web app that provides a dashboard of patient progress and remote control over the game is described in Section 4.6.4.

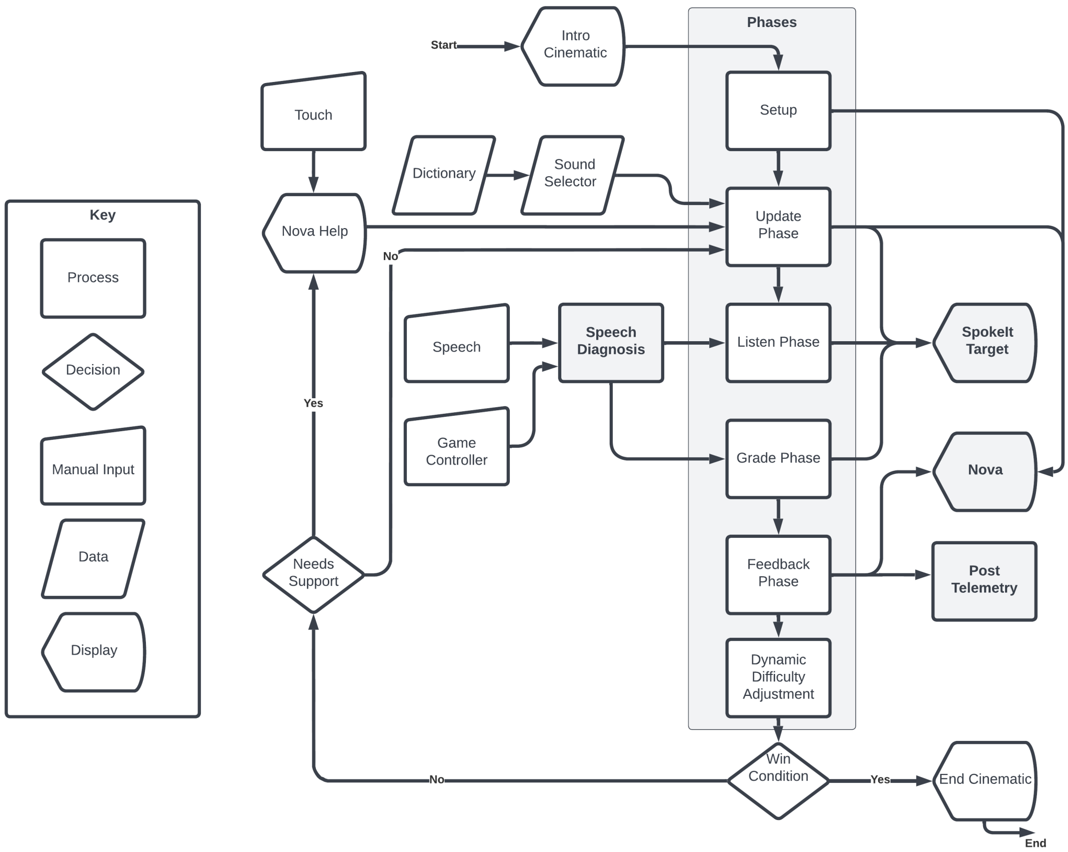


FIGURE 4.12: An abstracted flowchart of the SpokeIt Framework

4.6.1 Framework

The resulting implementation is written in Swift 5 using Apple's Spritekit framework. A simplified flowchart that provides an overview of the SpokeIt Framework is shown in Figure 4.12. Important classes that have their own section are bold and gray in the figure. The remaining Flowchart elements are described in Section 4.6.1.4.

4.6.1.1 Speech Diagnosis

There are 2 speech articulation recognition systems that are used in tandem. The first is the customized OpenEars implementation described in Section 4.3.5.4. The second is an online system built in the Cloud to deliver more accurate distinction of correct and incorrect pronunciations on a larger dictionary of mispronunciations.

The offline recognition occurs in real time but is less accurate. The cloud system is slower due to network latency, but is more accurate due to the higher computing resources. The local system gives players immediate feedback while they speak and then the final grading of each speech round is completed by the online system, if available. If the player is offline, SpokeIt still functions, but is less accurate. The Speech Controller module handles the asynchronous events fired by both speech systems.

SpokeIt supports the surrounding expertise of those who may be with the child via an optionally connected game controller. If a controller is connected, the speech systems still operate in the background, but SpokeIt delegates the decision on whether or not the speech was correct to the input of the person holding the controller. This approach has 4 benefits:

1. The input represents expert evaluation that can be compared to the decisions of the speech systems operating in the background and used to improve the machine learning accuracy
2. Accessibility is increased because the controller can be used in lieu of the algorithms that may be overly critical or inaccurate for a particular player
3. The magic circle is widened and facilitators can introduce their own mechanics (e.g., jumping jacks) to keep the player engaged
4. The pace is set by the facilitator who can read the player's body language and has knowledge about their interaction style and abilities

The ability to use a game controller in lieu of the speech recognition systems for open-ended play gives facilitators access to the benefits of Wizard of Oz [23].

The Speech Controller also delegates streams of audio data to modules that provide functionality beyond the speech articulation systems. For example, SpokeIt uses a machine learning model that distinguishes children's speech from adults' speech, shown in Figure 4.13, to prioritize children's speech when they are playing with their parent. I have also developed models to recognize speech errors that are common among children born with a cleft, such as hypernasality, hyponasality, and glottal stops, but these are disabled in SpokeIt due to their current low accuracy. Because they are disabled, I do not provide in-depth details in this dissertation other than gratitude to Smile Train[1] for entering into a Data Sharing Agreement with me that enabled their creation and the potential for SpokeIt to support more types of speech diagnosis in the future. Additionally, due to limitations imposed by the COVID-19 pandemic, there was no availability to formally measure the accuracy of SpokeIt's speech diagnostics because access to healthcare facilities was limited. However, each of the speech language pathologists who have tested SpokeIt were impressed with the accuracy of the articulation recognition systems and indicated interest in adopting SpokeIt in their practice. In my future career, I will continue improving SpokeIt's ability to diagnose speech following release.

4.6.1.2 SpokeIt Target

When a player speaks, there are three SpokeIt Targets on screen that indicate to the player what the target words are for their speech therapy. The SpokeIt Target is composed of multiple elements. The first is a label spelling out the word and changing colors based on speech performance in real time. The second is a custom SpokeIt-themed illustration that visually and metaphorically represents the target word. The third is a particle system of yellow stars that uses the illustration as an alpha mask as one of the indications that the player said the word correctly. Finally, there is another particle system that generates sparkles around the borders of the screen that indicate when the Speech Diagnosis system is actively listening.

[1] `https://smiletrain.org`

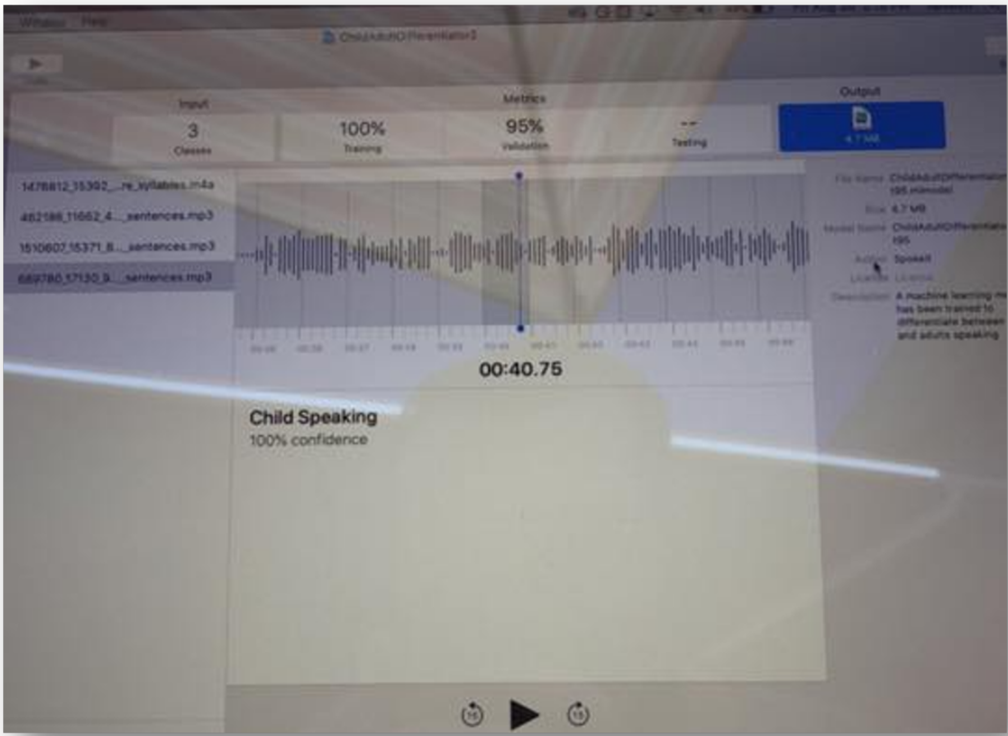


FIGURE 4.13: 4.7 megabyte neural network machine learning model developed in Apple's CreateML that distinguishes between adults' and children's speech with 95% accuracy based on a Data Sharing Agreement with Smile Train

4.6.1.3 Nova

Nova is the narrator of SpokeIt and represents both the facilitator and support. Nova has custom lip animations and professionally recorded voice acting to correctly demonstrate how to say each target. There are settings for Nova to automatically demonstrate each word in the Update Phase (default) or only when the SpokeIt Target is tapped for faster gameplay. Additionally, Nova provides the closed captioning functionality. Nova has user interface animations that look like "star magic" to highlight areas of the screen when giving instructions or providing contextual support (which also has lip sync animations).

4.6.1.4 Phases

The setup phase is used by the child minigames to place all of the game elements and give instructions on how the minigame is played. The Update Phase chooses the target words for the three SpokeIt Targets and plays a "reset" animation to place or replace those targets. Targets that were said incorrectly remain for two rounds. Targets are chosen based on words in the Dictionary that fit the Sound Selector's criteria. During the Listen Phase, SpokeIt Targets react to speech based on events posted by the Speech Diagnosis module—which can take the form of speech input heard by either recognition system (prioritizing the online system's higher accuracy) or game controller input. Players can say words in any order and repeat words that the system highlights as incorrect. Players can speak for up to 10 seconds to keep trying, but if there is one full second of silence, the Speech Diagnosis Module will progress from the Listen Phase to the Grade Phase. During the Listen Phase, SpokeIt Target labels will turn orange if a mispronunciation was heard and light green when speech was correct. If correct, a star particle system will make the target illustrations appear imbued with magic. The particle system that creates sparkles around the border of the screen reacts to speech by briefly increasing particle birthrate when words are heard. These sparkles will briefly turn from yellow to green if a correct word was heard. They will flash red and play a "screechy" sound if a mispronunciation was heard. In the Grade Phase, the labels of the SpokeIt Target will change to their final color—red if incorrect and dark green if correct. Nova will play a magical starburst and pleasing sound over the targets that were said correctly. The incorrect targets will remain or disappear based on how many times the player has incorrectly said the target or omitted it. In the Feedback Phase, Nova will make a comment about how successful the player was and each respective minigame will react either positively or negatively based on the speech performance of the player. All of this data is posted to SpokeIt's online telemetry system. SpokeIt's dynamic difficulty adjustment is described next.

The Dynamic Difficulty Adjustment phase intelligently sets the next speaking round's difficulty based on prior performance and decides whether or not Nova should provide additional support and checks if the win condition was reached for the minigame. SpokeIt has four levels of difficulty. At the hardest level, all three visible targets need to be said correctly in order for a positive result in the minigame. The next step requires two out of three targets correct and so on. The easiest level of difficulty does not require any words to be said correctly—players need only make a sound. If the player had a positive result, the difficulty of the next round is set one step higher, with a maximum value of 4. If they had a negative result, the difficulty of the next round is set one step lower. If the player has two successive rounds of decreasing steps, Nova provides additional support in the form of tips on game usability features, repeated targets spoken aloud, and minigame instructions. Based on whether or not the win condition was satisfied, the final cinematic for the minigame is played or another round is initiated at the Update Phase. The final cinematic is always a celebration of winning the minigame because the dynamic difficulty adjustment makes it impossible to lose.

Dynamic speech therapy curricula are important as each player will have unique speech therapy goals, such as saying words that start with "s" or words with many syllables. To successfully integrate SpokeIt into the healthcare context, SpokeIt must be customizable. SpokeIt is capable of focusing on targeted initial sounds for specific minigames.

4.6.1.5 Telemetry

Telemetry is a process by which measurements and other data are collected automatically and remotely for monitoring. SpokeIt is equipped with a telemetry system that records many types of events such as words that are said correctly and incorrectly, logs of when and how often SpokeIt is played, logs of when SpokeIt offers contextual support, and audio recordings of players' speech. This telemetry can provide insights into how speech performance changes over time, which games are preferred, and where to make usability and speech system improvements. The audio recordings are used to train the machine learning models.

4.6.2 Minigames

Each minigame inherits from the SpokeIt framework I developed and is based on the participatory design described in Section 4.4. The art for the minigames was made by Marina Juanet [2]. I created the tutorial minigame and the Space Trash minigame as examples of how to use the SpokeIt framework, described below. High School Summer interns participating in the Science Internship Program[3] from 2018-2021 implemented the remaining minigames and animated the lip sync used by Nova under my guidance. Each minigame fits within a circular overarching narrative following the order presented in the following subsections where Eliza leads back into Space Trash, resetting the cycle. Only one minigame can be played per day to achieve the goal of practicing for 10 minutes per day set by the medical professionals that I collaborated with.

4.6.2.1 Tutorial

The Tutorial, shown in Figure 4.14, serves two purposes: to introduce the player to Nova's story and to teach the player that their voice controls the game. Nova is an author in space who observes many planets and documents the stories. Hearing these stories is the source of her magic. Nova spent her life in the sky as an observer, but wishes to have an adventure of her own. Because she is no longer in space listening, she asks the player to charge her magic using their speech. Nova

[2] http://www.marinajuanet.com
[3] https://sip.ucsc.edu

FIGURE 4.14: Screenshots of SpokeIt Tutorial depicting Nova changing colors based on player's speech

demonstrates the player's ability to charge her by asking their favorite color and transforming her body to match that color. Eliciting speech from the player for the first time is challenging because it is not a common mechanic, so the prompts were carefully scaffolded in. After changing colors, Nova describes the features of the SpokeIt Target described in Section 4.6.1.2. After a few rounds of practice, Nova is charged enough to venture to her first destination, which leads into the Space Trash minigame. The tutorial is the only minigame that is always available. The other minigames rotate once per calendar day that players use the game.

4.6.2.2 Space Trash

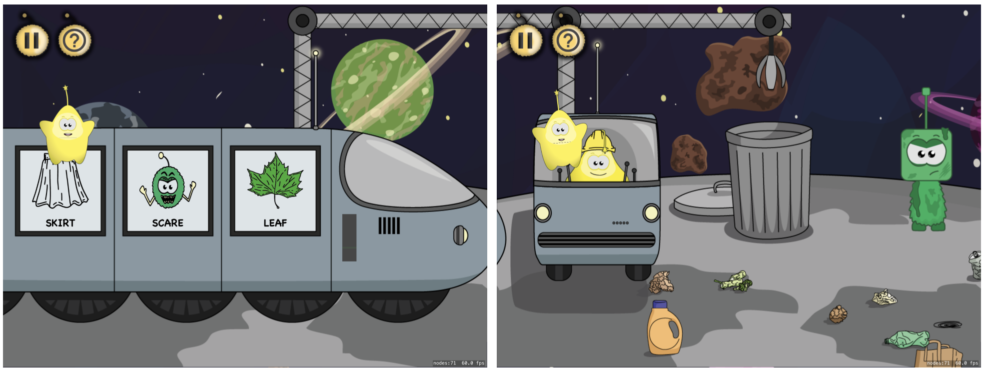


FIGURE 4.15: Screenshots of Space Trash minigame depicting player using their speech to charge the machine that removes trash off of the messy moon

Space Trash is played immediately after the Tutorial. This minigame introduces Nova and the player to Allen the Alien, a grouchy sounding creature with no arms that asks Nova to help him clean up the trash on the moon. Nova is happy to help but needs the player to charge her magic so she can operate a crane that picks up the items one-by-one. The speech targets appear on the side of the crane and a fuel meter indicates the power needed to pick up the next piece of trash. Notches on the meter are updated based on the dynamic difficulty system described in Section 4.6.1.4 If the player meets the threshold needed, the crane picks up the item and places it in the garbage can. Otherwise, the machine shakes and plays a powering down noise, unable to pick up the trash. After the moon is cleared, Allen abruptly halts Nova from removing one last piece of trash—which happens to be a treasure map. Following, Nova is advised to visit the planet inhabited by a race of characters called the Migs, who Nova has never heard of because they do not speak.

4.6.2.3 Boat Adventure

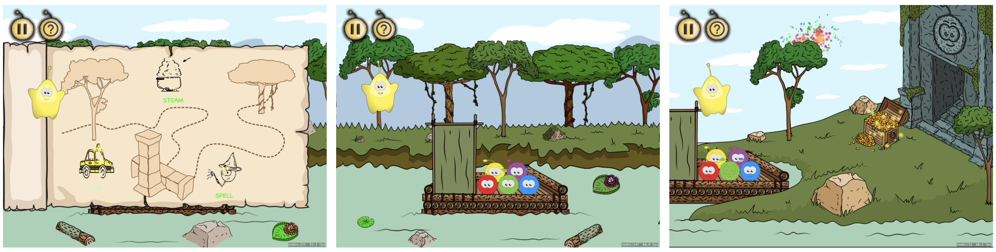


FIGURE 4.16: Screenshots of SpokeIt Boat Adventure minigame depicting the speech targets on the magic map, the boat advancing down the river, and the treasure chest at the end

In the cinematic that introduces the Boat Adventure minigame, as Nova approaches the planet inhabited by the Migs, she gets too close trying to listen for sounds and crash-lands due to the pull of gravity. As she wakes, she is greeted by the Migs who agree to join her on the treasure hunt. They find a boat along the River, but Nova needs the player to say target words on the magical map to produce wind that propels the boat. The Migs do not speak, so the player's help is required. Depending on how well the player performs, the boat moves at a slow speed, medium speed, or fast speed. Faster has more exciting effects within the game, but regardless of performance, as 10 minutes of gameplay approaches, the island with treasure is reached accompanied with fireworks and an animation of the boat docking. In the chest, a part belonging to a musical instrument is found. The Migs are excited about the instrument component but do not have arms to play, so Nova offers to help them put on a concert using her magic.

4.6.2.4 Musical Migs

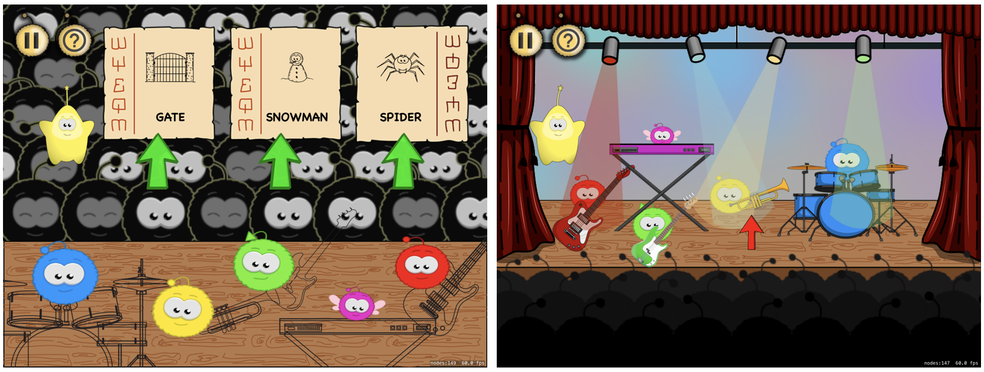


FIGURE 4.17: Screenshots of SpokeIt Musical Migs minigame depicting audience posters with target words to charge the instruments and the resulting stage scene where the song is composed of instruments that were successfully charged

The Musical Migs minigame starts with a cinematic of the theater at which the upcoming concert will take place. Nova highlights the instruments on stage one-by-one and transforms the audience's posters into target words. Each round of speech either charges the highlighted instrument or does not. The Migs react by showing excitement or briefly crying depending on whether or not their instrument was charged. Additionally, after each round, the instrument will briefly play a riff or make an off sound depending on the outcome. After going through each instrument, the scene changes to dancing lights and confetti while the Migs play a riff. The stems in the riff include only the instruments that were charged. The audience cheers and wants an encore. The process of charging all the instruments and playing the riff repeats once. After the concert, an audience member gifts the Migs a strange mechanical component.

4.6.2.5 Eliza

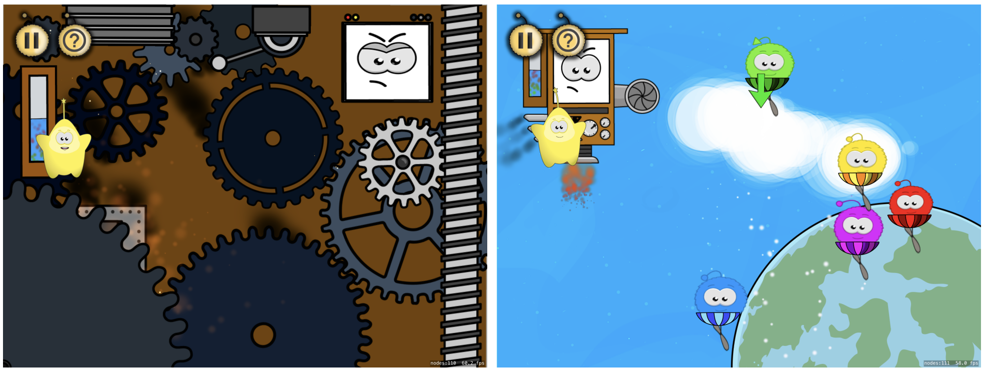


FIGURE 4.18: Screenshots of SpokeIt Eliza minigame depicting the internal components of the antagonist, Eliza, cycling in targets and the outside scene where Eliza adds or removes storms based on player performance

Eliza, the game's antagonist begins with a dramatic cinematic. Outside of the concert hall, a heavy wind picks up, scaring the Migs, They all look up and the camera pans to the sky where a flying machine is creating clouds of storms that surround the planet. Nova learns that Eliza is a malfunctioning machine that was originally intended to fix the climate. The Migs use upside-down helicopter hats to fly up to Eliza and Nova enters the machine. Inside, misaligned components appear through smoke and sparks. With the speech magic provided by the player saying the targets on the components, Nova can reconfigure Eliza. Inside the machine is a meter filled with "Storm Juice" that fills or empties based on performance. If the bar fills, Eliza shows an evil smirk and creates a new storm. When empty, Eliza removes a storm from the atmosphere to partially fill the tank back up. Once all of the storms are removed, Nova provides a temporary fix by installing the component received in Musical Migs and Eliza is convinced to leave. The Migs celebrate but the storms stirred up more trash on the moon, resetting the cycle of minigames.

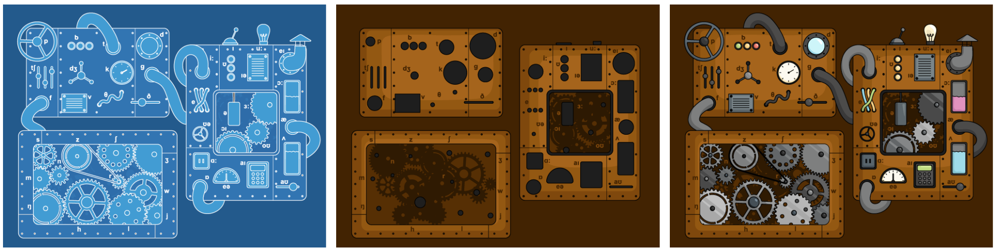


FIGURE 4.19: On the left, the blueprint of Eliza. In the center, Eliza without components. On the right, Eliza filled with all components

4.6.3 Winning SpokeIt

SpokeIt can continue to provide speech therapy for as long as it continues to be a valuable tool for practicing speech because of the circular narrative. However, the ability to celebrate progress and eventually win is important. After the first iteration of playing through the minigames, the player is given blueprints to fix Eliza for good. In order to fix Eliza, the player must collect and install all of the components in the blueprint. Each component represents a speech sound that the game supports. The blueprint and machine have labels embossed for each of the components to clarify which sounds are completed and which are missing. A player is awarded each component when either a speech therapist or the game (if not connected to a therapist's account, described in Section 4.6.4) is satisfied. Components can break and fall off if needed. Once Eliza is returned to their intended state, she gives Nova a rocket ship that allows her to return to space and start her next adventure.

4.6.4 Companion Web Application

The SpokeIt Companion App Figma[4] prototype is based on the generalizable knowledge generated from my work with medical professionals on Spellcasters, described in Section 5.4.5. Medical professionals, including speech therapists, have large case loads. Therefore, it is important that they have frictionless access to

[4] https://www.figma.com

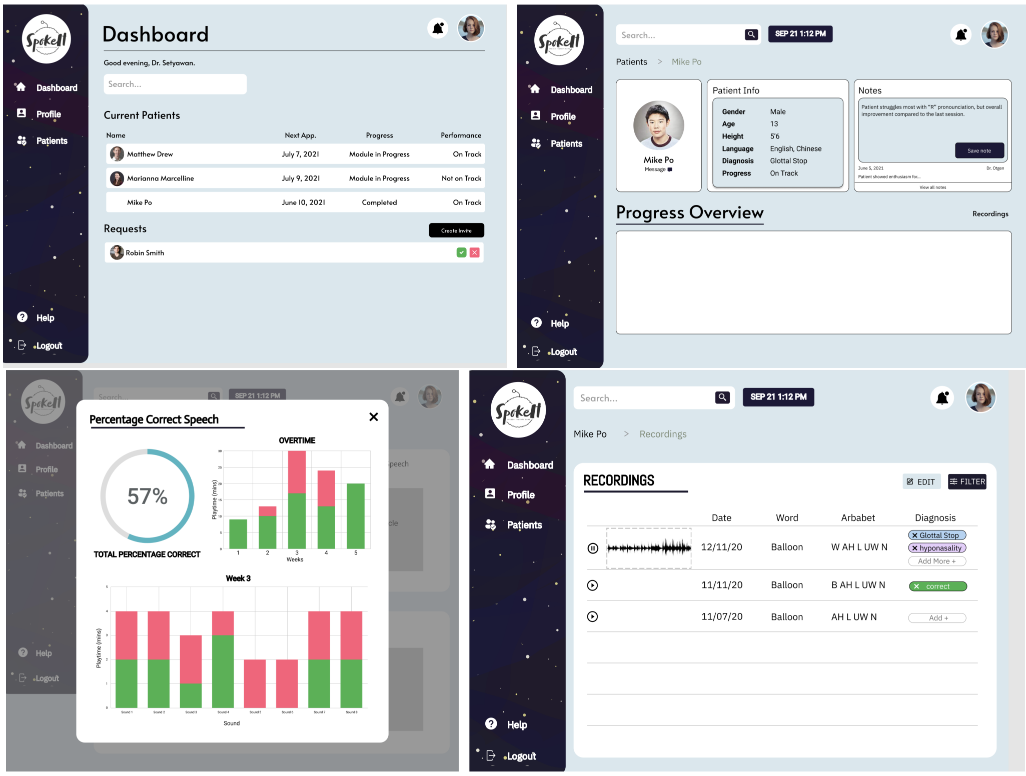


FIGURE 4.20: Screenshots of the Figma prototype for the SpokeIt Companion Web Application. Top-left: A dashboard view of a medical professional's case load. Top-right: The profile of a patient. Bottom-left: Placeholder Data visualizations. Bottom Right: Speech file diagnosis tagging interface.

intuitive data visualizations, progress reports, and remote control over the game. It is unlikely that these professionals will have time to log into each child's device to access their data and adjust their speech curriculum. The dashboard provides an at-a-glance summary of their patients who have upcoming appointments and those who have used SpokeIt recently. The patient profile provides a detailed view of the child's diagnosis, goals, reports, and access to a sound selector that allows the speech therapist to remotely tune SpokeIt's curriculum. The placeholder data visualizations show quick-to-digest metrics of patient performance, but these will need to be replaced in the future by co-designed graphs from future participatory design workshops with speech therapists. An integral feature of the companion web app is the speech file diagnosis tagging interface because it allows professionals to listen to their patients' speech and confirm or change the automatically-generated diagnosis from the machine learning, which is important data that can be used to continually improve the models' accuracy. Additionally, medical professionals can send messages through the companion app that will send a notification to the patient's device, which may be motivating for the children.

4.7 My Role

I was the primary lead of SpokeIt. I led all of the research, studies, design, and implementation. SpokeIt is my primary doctoral contribution. I implemented the SpokeIt framework, Tutorial, Space Trash Minigame, speech systems, machine learning, particle systems, and cloud infrastructure. High school students participating in the Science Internship Program[5] implemented the remaining minigames and completed most of the custom lip sync animations. Mary Mason and Sean Smith voice-acted SpokeIt. Marina Juanet did most of the illustrations for the game. Approximately 20 undergraduate and masters-level researchers helped me run studies, created the Figma prototype for the companion web app, and began implementing a version of SpokeIt in Unity Engine for Android. My co-advisors supported the research and provided guidance. My collaborators, Ferran Altarriba Bertran and Elena Márquez Segura were integral to collaborating on the development of the methodological protocols for SpokeIt.

4.8 Future Work

There is much promise for SpokeIt to continue making novel research contributions. Most importantly, SpokeIt would benefit from a longitudinal study that measures both SpokeIt's effect on speech performance and speech confidence. Following release, SpokeIt's telemetry system will be able to provide insights into in-the-wild use of a serious game for health. The data collected can be used to

[5] `https://sip.ucsc.edu`

improve machine learning accuracy and develop more models that children will benefit from. The companion web application needs more participatory design work, but once completed, represents an interesting research potential of studying how it impacts the relationships between medical professionals, children, and parents. Because the App Store will allow anyone to download and play SpokeIt, including unintended populations (e.g., language learners, stroke survivors, Parkinson's disease patients, non-verbal autistic people), it will be important to research how SpokeIt—or spin-off products—can be supported. My partner, Smile Train, is interested in collaborating on translating SpokeIt into new languages to support more countries, which is an interesting research case of how Western medicine interacts with other cultures and diverse healthcare systems.

4.9 Limitations

The largest limitation of this work is that the efficacy of the game on speech therapy and speech confidence have not been formally evaluated. Another limitation of this work is the low accuracy of some of the machine learning models that are intended to diagnose speech errors common in children born with a cleft other than articulation errors. However, with more data, I am optimistic that these will improve and be enabled within SpokeIt. The final limitation worth mentioning is the inclusion of participatory work from populations other than children with cleft speech, but as the research developed, the problem was reframed [18] to narrow the scope to focus this doctoral work on children born with a cleft. However, I would argue the contributions made by those other populations make the work stronger.

4.10 Reflection

The initial approach to SpokeIt prioritized the medical model, which remains a heavy influence on the design. The therapy-first perspective SpokeIt provided was a point of frustration towards the middle of my doctoral research because there were too many variables to account for and formally improving speech became less important to me than helping people improve their speech confidence. Speech therapy is a normative process and if accuracy takes precedence over all other goals, it becomes an ableist process. Speech therapy should be about providing tools, feedback, and support for reaching one's individual goals to be a confident communicator. Early prototypes employed an overly critical speech algorithm that negatively affected usability and enjoyment leading to frustration and abandonment. Games should challenge us without angering us to the point of quitting—they should motivate us to keep playing. My initial programming provided no flexibility in an attempt to be medically valid and scientific—the simple addition of supporting a game controller opened many new possibilities and contexts of play. This insight inspired me to explore a game-first approach rather than a therapy-first approach and explore designing for more flexibility through less structure.

Chapter 5

Spellcasters

5.1 Introduction

In this chapter, I present Spellcasters [235], a virtual reality stroke rehabilitation game designed to support stroke survivors with hemiparesis. Spellcasters was originally developed as an entertainment game where teams of five wizards with individual roles such as tank, support, or fighter battle in a magical duel. Each team has a pool of lives and the team that runs out of lives first, loses. The original Spellcasters featured a gesture-tracing mechanic to cast spells that showed promise for use in upper-limb stroke rehabilitation, so I lead the research on adapting the game for use as physical therapy. Spellcasters represents a game-first approach rather than a therapy-first approach (opposite of SpokeIt) because it began as a game and was repurposed later.

Potential benefits of repurposing existing entertainment games for therapy include reduced costs and development times with some promise for appropriating already-fun mechanics [190]. During a global pandemic, when telehealth solutions are needed quickly, appropriating technology to serve a new purpose is particularly relevant. In this work, we explore the adaption and redesign of *Spellcasters*, an immersive virtual reality (iVR) game where wizards cast spells by making gestures with their wand (VR controller). The original implementation of Spellcasters is designed purely for entertainment, but the gesture-based spellcasting mechanic is intriguing because it shares many commonalities with upper limb rehabilitation exercises, including repetitions, accurate movements, and a varying range of motions that can be measured using motion tracking. Placing stroke survivors in VR has risks, so we begin our participatory approach by collaborating with 14 medical professionals to validate that Spellcasters is safe and medically vetted before co-designing with stroke survivors. To this end, we co-design an open environment for physical therapists and occupational therapists to create custom gestures for their patients to "cast" and collect preferences on features for optimizing Spellcasters for telehealth, including performance monitoring and goal setting. In this work, to protect stroke survivors from contracting the COVID-19 virus during the pandemic and from using untested non-specialized software, we focus on designing elements of Spellcasters that will be primarily used by medical professionals—namely a custom gesture creation sandbox for defining individualized stroke exercises (described in Section 5.4.1) and a companion app for remote monitoring and administration (described in Section 5.4.5). These developments could be generalized to other game domains beyond casting spells in future participatory work with stroke survivors.

The contributions of this work are 3-fold: (1) We contribute to a growing body of work that advocates for scalable telehealth games for affordable and equitable access to healthcare, (2) We provide insights from collaborating with medical professionals on how serious games for health can support a custom and adaptable physical therapy curriculum remotely, and (3) We share auto-ethnographic reflections on adapting existing games for therapy and including medical stakeholders in remote participatory design sessions.

5.2 Background

This section introduces what traditional stroke management and rehabilitation entail, related works using VR for stroke rehabilitation we are inspired by, and an argument for serious games for health as a potential solution space for scalable, customizable, and equitable healthcare delivery.

5.2.1 Stroke Rehabilitation

According to The National Institute of Neurological Disorders and Stroke (NINDS), a component of the U.S. National Institutes of Health (NIH), more than 800,000 people suffer a stroke each year in the United States alone, and approximately two-thirds of these individuals survive and require rehabilitation [236]. Stroke is a leading cause of serious long-term disability [237]. Moreover, the market size for stroke management was valued at 30.1 billion American dollars in 2019 and is expected to witness 6.3% compound annual growth rate from 2020 to 2026 [238]. In the wake of COVID-19, telehealth solutions have become increasingly relevant for delivering scalable remote healthcare solutions to curb the spread of the virus [239–241]. Physical and occupational rehabilitation for stroke typically requires long-term and consistent intervention [242] with many challenges to keep stroke survivors motivated [243]—a unique challenge that games have successfully navigated in many contexts [85, 171, 244] including mental health (e.g., [40]), physical health (e.g., [56, 86, 95, 97, 119, 245]), and speech therapy (e.g., [192]).

Stroke survivors often experience a range of impairments, including loss of balance, cognitive deficiencies, pain, weakness, and paralysis—resulting in difficulty with performing everyday activities such as bathing, eating, walking, and cooking [246]. In most cases, these effects of stroke are present on one side of the body, a condition known as hemiparesis [247]. Even though rehabilitation does not reverse brain damage, it can substantially help people achieve the best possible long-term outcome [242]. For some survivors, rehabilitation will be an ongoing process to maintain and refine skills for months or years after the stroke [242]. Stroke survivors tend to avoid using impaired limbs—a behavior called learned non-use. However, the repetitive use of impaired limbs encourages brain plasticity and helps reduce disabilities [248]. In practice, physical and occupational therapy emphasizes the performing of isolated movements, repeatedly changing from one kind of movement to another, and rehearsing complex movements that require a combination of coordination and balance. A recent trend in stroke rehabilitation emphasizes the effectiveness of engaging in goal-directed activities, such as playing games to promote coordination [236].

There have been many software interventions for stroke rehab (e.g., [56, 94, 117, 249–253]). Many input modalities have been explored including motion tracking (e.g., using the wii controller [117]), 3d sensors such as the Kinect or the Intel Real Sense (e.g., [251, 254, 255]), keyboards for fine motor control [256], shape changing robots [252], webcams that track colored objects [117], smartphones that track performance [257], and VR (e.g., [94, 249, 258–260]). Many of these software interventions are games—we discuss the benefits of using serious games for therapy in the next section. We present more details on VR for stroke rehabilitation in section 5.2.3.

5.2.2 Serious Games for Health

A serious game for health is a game created to entertain and achieve health goals [261]. Games are motivators and make otherwise tedious repetition engaging through gameplay [117, 247]. Many serious games have led to improved health outcomes (e.g.[262]). Video games improved 69% of psychological therapy outcomes, 59% of physical therapy outcomes, 50% of physical activity outcomes, 46%

of clinician skills outcomes, 42% of health education outcomes, 42% of pain distraction outcomes, and 37% of disease self-management outcomes [89]. Learnability, flexibility, and robustness are core paradigms to creating usable and valuable serious games for health [263]—the ability to customize serious games for health for the heterogeneous needs of stroke survivors is integral to our work.

5.2.2.1 Customizable Serious Games for Health

It is important that therapy games be customizable because players have individual abilities [264], therapy goals [242], and motivations [265], similar to the concepts of player archetypes [266]. We found Alankus et al.'s insights on multimodal inputs, feedback, and breadth of games inspiring in the stroke rehab games context [117]. We are particularly interested in what medical practitioners find important for custom stroke rehabilitation in this work. There are various types of motions that therapy games designed for upper extremity should cover; these include: shoulder abduction and adduction, shoulder flexion and extension, shoulder internal and external rotation, elbow flexion and extension, wrist rotation, flexion and extension, hand and finger flexion and extension, grasp, move, release, and reaching [117]. 3D depth sensors can track most of these motions [254] as well as VR devices [267] by using the standard motion controller. Not all of these exercises are accessible to each stroke survivors' abilities [242]. In this work, we are interested in leveraging these sensing abilities in ways that are customizable and adaptable to the individual needs of each player. The affordances of scalable technology allow adaptive therapy experiences for telehealth, described below.

5.2.2.2 Telehealth and games

Benefits to telehealth interventions such as VR stroke rehab games include scalability [268], increased access [269], customization [268], and rich data-driven insights based on large data sets and artificial intelligence [270]—an approach common in game user research, called telemetry [271]. In this work, we are particularly interested in the reporting features clinicians are interested in to make informed insights into their patient's progress both at home and outside the clinical setting. Telehealth affords interactive contact, allowing for day-to-day tracking of improvement and modification of recovery plans. The benefits of using telehealth may boost the efficiency of stroke therapy with more prompt and regular evaluations and better consistency across the healthcare chain.

5.2.2.3 Telehealth and COVID 19

Due to the COVID-19 pandemic, many inpatient rehabilitation facilities and services have emergency preparedness plans in place to curb the spread of the virus, including cancellation of non-required therapies such as physical, speech, and occupational therapy [272]. Medical professionals and patients who have looked towards telehealth opportunities have been met with complex barriers, including limited options and lack of insurance coverage [272].

It can be challenging to include people with disabilities in participatory work generally [273], but there is a specific added risk during a global pandemic. Co-design sessions should be valuable to all parties [274], but they disrupt everyday life and require participants to invest their precious time. In addition to general guidelines that limit in-person contact, populations of people with disabilities often have medical needs that place them at higher risk from the COVID-19 virus [241]. In the context of quarantine requirements, designers are employing creative methodologies to carry out remote design work that is usually done in situ [240] (e.g., using games to educate the public about COVID-19 and collect data [275]). Many of these technologies are not accessible to people with disabilities [239]. To this end, in this work, we focus on co-designing *Spellcasters* with medical professionals to ensure its medical safety and efficacy before working with stroke survivors after the COVID-19 vaccine is widely administered. We concentrate on designing an intuitive environment for medical professionals to create custom and adaptive gestures for their patients' needs as well as tools for tracking and reporting on progress for telehealth. We argue that drawing inspiration from existing games developed for entertainment provides some insurance that the game will have entertaining mechanics without risking the health of stroke survivors or subjecting them to inaccessible remote protocols. The groundwork for the rehabilitative custom gesture system we develop in this work could be utilized and expanded to domains and themes beyond spell-casting in magical worlds, based on future participatory work with stroke survivors. If, however, stroke survivors enjoy the magical domain, we can contribute further anecdotal examples on the value of appropriating from entertainment games for therapy through this design choice that protects the health and well-being of stroke survivors in the current pandemic climate.

5.2.3 Virtual Reality for Stroke Rehabilitation

VR for physical rehabilitation with stroke has seen an extensive exploration over the past decade due to the potential to use gaming to motivate and guide users through repetitive therapy exercises. Immersive virtual reality (iVR) refers to the sensation of being physically present in a non-physical environment. The perception is generated by enveloping the user of the VR system with visuals, sounds, or other stimuli that create a complete and engaging experience. Non-immersive virtual reality, unlike iVR, delivers an identical picture to both of the user's eyes. As a result, people experience this picture in just two dimensions: height and breadth, but fully iVR technology offers a digital image in three dimensions: height, width, and depth. Non-immersive VR games were explored as early as 2007 with systems such as Microsoft Kinect [251], PlayStation [276], and Nintendo Wii [250], demonstrating feasibility in tracking patient progress and improving compliance through these motion-based controllers. Multiple reviews have suggested that VR-supported mediums for stroke rehabilitation can be effective in improving patient outcomes compared to traditional stroke therapy due to the ability to simulate controlled interactive environments for exercise guidance and quantitative data capture [251, 277, 278]. Moreover, hundreds of studies throughout the past decade support the utility of VR for motor rehabilitation, with many reporting significant improvements in compliance and/or recovery [94, 95, 250, 251, 279–281].

In 2021, the consumer market saw widespread adoption of iVR, enabling full-body movement and 360-degree viewing of the virtual world through head-mounted display (HMD) systems. These systems are becoming increasingly immersive, accurate at capturing human motion, and are projected to reach 30 million sales per year by 2023 [282]. More recently, the academic community has begun investigating the usage of iVR HMDs for post-stroke rehabilitation. Many studies have suggested that iVR HMDs can significantly improve post-stroke standardized upper-extremity motor tests. However, existing evidence is limited as there is a greater need in more studies to investigate the non-pharmacological therapeutic pathway of iVR for people after stroke [283].

There has been a growing interest in translating these motor rehabilitation exercises into iVR games for post-stroke. *Project Star Catcher* has demonstrated that iVR can benefit treatments such as Constraint-Induced Movement Therapy with stroke survivors by increasing compliance up to 40% when compared to traditional methods and providing an accessible medium for capturing patient success metrics with HMD motion capture [94, 284]. *Project Butterfly*, an iVR experience inspired by Mirror Visual Feedback Therapy, has explored the potential to engage patients for long-term treatment with immersive virtual environments, which is vital because stroke rehabilitation can span years [285, 286]. *REINVENT* applied neurofeedback systems to iVR games with promising pilot results suggesting feasible and safe usage for severe stroke upper limb motor recovery [287]. Additionally, some studies have begun testing commercial entertainment-based iVR exercise games (e.g., *Beat Saber*) for users with chronic stroke and found that long-term gameplay can improve patient results for standardized upper extremity motor function tests [288]. While many iVR solutions exist for stroke rehabilitation and suggest promising results, there is an inherent need for more validation within the academic community to investigate iVR HMD based design and clinician needs [283]. Thus, in this paper, we examine the usage of gesture-based exercises for an iVR HMD experience from clinician perspectives by repurposing an entertainment-based game for stroke rehabilitation as a precursor to participatory work with stroke survivors.

5.3 Method

The primary goal of this work was to redesign and adapt an entertainment-based exergame for stroke rehabilitation. In this work, we focus on the intuitive software medical professionals will use for creating custom rehabilitative gestures for their patients' unique and heterogeneous needs. Based on our literature review and initial interviews with physical therapists, we defined three research questions that drove our development and evaluation of *Spellcasters*:

RQ1: *How do clinicians want to customize the therapy exercises towards an accessible primary spell-casting game mechanic (gesture creation)?*

RQ2: *What data, visualizations, and reports are clinicians interested in for clinical decision making?*

RQ3: *How can Spellcasters support the telehealth needs of the COVID-19 era?*

These contributions aim to ensure that Spellcasters is safe and medically vetted before engaging in future participatory work with stroke survivors for prototyping iterations. The research questions above are exploratory and afford a qualitative and iterative Research through Design approach [2, 161].

5.3.1 Software

Due to the COVID-19 pandemic restrictions, we employed a fully virtualized human subjects protocol completed online over *Zoom*[1], a video-based teleconferencing platform with screen-sharing capabilities. *Spellcasters* is an immersive VR game that requires a head-mounted display (HMD) system, but not all medical professionals have access to these devices. Consequently, we employed separate procedures for those with and without supported VR HMD systems, described below in Section 5.3.3. We used *Google Sheets*[2] to analyze and transcribe the recordings, grouped by interview question (included in our supplementary materials and live at `https://tinyurl.com/Spellcasters-Supplementary`). A shared executable file of the game's build was given to all participants who had access to a VR system during the interviews. Additionally, a mockup interface was shared through *Figma*[3], an industry-standard software for rapid prototyping of user interfaces, to iterate and evaluate a companion app described in the *Spellcasters* Section 5.4.

[1] `https://zoom.us/`
[2] `https://www.google.com/sheets/about/`
[3] `https://www.figma.com/`

5.3.2 Participants

The participants recruited in this study consisted of physical and occupational therapists with experience in post-stroke rehabilitation. Recruitment was conducted by reaching out to medical professionals in rehabilitation leadership positions (e.g., chapter presidents of the United States American Physical Therapy Association[4]) followed by Snowball recruiting [289] and posting recruitment fliers on social media groups for rehabilitation. Through this process, 14 medical professionals were recruited to participate in this study, with corresponding demographics illustrated in Table 5.1.

	Sex	**Role**	**State**	**VR HMD Access**	**Companion App**
P1	M	Physical Therapist	Ohio	✓	X
P2	M	Physical Therapist	Kansas	X	X
P3	M	Physical Therapist	California	X	X
P4	M	Physical Therapist	Minnesota	✓	X
P5	M	Physical Therapist	California	X	X
P6	F	Physical Therapist	Michigan	X	X
P7	M	Physical Therapist	California	X	X
P8	F	Physical Therapist	Virginia	X	X
P9	F	Occupational Therapist	Ohio	✓	X
P10	F	Physical Therapist	New York	X	✓
P11	F	Physical Therapist	New York	X	✓
P12	F	Occupational Therapist	Massachusetts	X	✓
P13	F	Occupational Therapist	Washington D.C.	X	✓
P14	M	Occupational Therapist	Washington D.C.	X	✓
Totals:	7 Female : 7 Male	10 Physical : 4 Occupational	11 Unique	3 Self VR Access	5 Self Companion Access

TABLE 5.1: Participant Demographics.

5.3.3 Procedures

With the consent of the participants, all virtual interviews were recorded for post-analysis, with each session lasting between one to two hours (with all materials used in the procedure of evaluating *Spellcasters* shared at `https://tinyurl.com/Spellcasters-Supplementary`). Sessions began with a set of preliminary semi-structured interview questions inspired by [271] to understand each

[4] `https://www.apta.org/`

medical professional's experience and practices related to stroke recovery. We included questions related to their openness, experience, and expectations for physical therapy games (*RQ1*). We asked how they currently collect data, communicate with insurance providers, and set goals (*RQ2*). Pre-surveys were concluded with questions on how COVID-19 has changed their practice if they have adopted telehealth and reflections on if and how they measured progress made by patients outside of their appointments (*RQ3*).

After the preliminary interview, participants experienced *Spellcasters* either directly with their own VR HMD or indirectly by seeing a mirror of the research teams' HMD view. In both cases, gameplay and user interaction were mirrored in video using the *Zoom* screen sharing feature so everyone could see the game and record the gameplay for later analysis (including game audio). Medical professionals without VR HMDs were asked to instruct the researcher on how to play similar to a Think Aloud protocol [271] (*RQ1*).

As the Research through Design process progressed, it became clear that medical professionals would benefit from a companion app, described in Section 5.4.5 (*RQ2*, *RQ3*). Subsequently, the procedure was adapted to explore this interaction for *Spellcasters*, where participants tested a companion app designed in Figma using the Think Aloud protocol [271]. Participants freely explored the app during this phase, provided initial impressions, discussed confusing elements, and shared design recommendations. We were particularly keen to know which data visualizations the medical professionals were interested in (*RQ2*), so we asked participants to describe how they interpret each graph, asked them if there was a more appropriate format they prefer, and if there were any elements that could be added to make the graphs more intuitive. We iterated on the Figma prototype between sessions to incorporate each participants' feedback. We continued this cascading iterative process until a critical mass of participants could understand the graphs and found them intuitive and valuable.

Finally, participants were asked a set of closing semi-structured interview questions [271] (*RQ1*,*RQ2*, *RQ3*), provided in the supplementary materials [5], so that we could evaluate the prototypes and recruit more participants. After each session, the game and companion app prototypes were iterated based on observations and feedback. The highly iterative Research through Design approach led to many insights towards answering our research questions.

After completing all Research through Design sessions, medical professionals were asked to complete a follow-up survey and 8 out of 14 completed the survey. We included the Spellcasters trailer in the survey to highlight the iterative updates to the game since their playtest. The Figma prototype was also linked in the survey so the participants could experience the most up-to-date version. The survey consisted of 9 Likert questions asking participants to rate how much they disagreed or agreed with the 9 statements.

All of our transcriptions and summaries are available in the supplemental materials for transparency[6]. We sorted responses for each question by each participant in a document table that includes summaries of each question, giving equal weight to all feedback. In our results section, we organized these summaries into themes inductively, taking careful precautions to reduce bias by including both positive and negative feedback from our participants.

5.3.4 Ethics

This research was reviewed and approved by the institutional ethics review board. An important consideration was COVID-19 and the added risk many stroke survivors would face if they participated in this research, whether in-person or remotely. In-person protocols would be hazardous because they would place stroke

[5] https://tinyurl.com/Spellcasters-Supplementary
[6] https://tinyurl.com/Spellcasters-Supplementary

survivors at risk of infection. However, remote participation is also dangerous because the software many of us have come to rely on during the pandemic is not accessible [241] and without medical supervision, playtesting and co-designing *Spellcasters* before it is medically vetted could also result in injury. Our institutional ethics board mandated that we first work with medical professionals before designing and testing with stroke survivors, which we agree protects stroke survivors from unnecessary risk during the pandemic. We believe including people with disabilities early and often in the design process is critical, which we will discuss in the next paragraph. However, given the circumstances of the pandemic, we decided to work exclusively with medical professionals and leave the game world open-ended for future participatory work with stroke survivors once the vaccine has been widely administered.

Over a decade ago, ASSETS scholars called for the use of a critical disability lens while designing and developing assistive technology for disabled individuals [290]. This call has only strengthened in the proceeding years, with an emphasis on allowing for more co-design and co-research with disabled people [291–293]. To summarize the concern, the majority of assistive technology devices and applications are rooted in medical discourse. That is, disability is an inherent problem in the body and must be "fixed" or "normalized" by intervention. Using a more socially-oriented lens, such as those found in disability studies, emphasizes the social context and environment as *creating* disability by denying access to particular body configurations [294–296]. Given this concern about the discourses that influence the design of assistive technologies, it has become even more important for researchers to acknowledge the needs of the disabled individuals the technology is meant to help. In future work, we intend to include stroke survivors in the design process for the gameplay surrounding casting of gestures made by medical professionals. We chose magic wands because the possibility space remains open for stroke survivors to choose further game directions. The Results section provides evidence that supports the magical spell-casting domain we have appropriated from the pure entertainment version of the game. However, if stroke survivors imagine other domains during our participatory design sessions, the gesture recognition system and environment for medical professionals to create custom exercises could easily be generalized to new domains.

Designing serious games for medical use is complicated due to the ethical responsibility that it entails. Specific game mechanics may seem fun to play, yet a poorly designed game may cause more harm when used practically with impaired users. As designers, we need to conduct research and trials to ensure our design suits our target audience. While designing Spellcasters, we have worked closely with medical practitioners to evaluate what set of features are needed and valuable for stroke survivors. From our research, we found that strokes are affecting increasingly younger populations. One medical practitioner (PT8) expressed that they treat stroke patients as young as five years old. Given this concern, our team studied pre-existing games and stories such as Waltz of the Wizard and Harry Potter—popular themes among younger generations. With the help of physical therapists, we can design our spells to resemble traditional therapy while maintaining an engaging experience. We envision this game supporting rather than replacing traditional physical therapy. With this game, we hope to help engage and motivate the stroke survivors to do their rehabilitation exercises prescribed to them more often because consistency and compliance are critical to their recovery.

5.4 Spellcasters

Spellcasters[7] is an immersive virtual experience designed in the *Unreal Game Engine*[8] *(v4.24.3)* that was repurposed from an entertainment-based exergame to

[7]Spellcasters Trailer: `https://tinyurl.com/Spellcasters-Trailer`
[8]`https://www.unrealengine.com/`

a medically informed therapy game for stroke survivors. *Spellcasters* was originally a game purely for entertainment where two teams of 5 wizards competed in a magical duel. Wizards had various roles on their team, such as tank, support, and melee—each with a corresponding spellbook and spells. Both teams had a pool of lives, and the last team standing won the round. The entertainment version of *Spellcasters* was developed in Unity and used an off-the-shelf machine learning-based gesture recognition system. When the stroke rehabilitation version of *Spellcasters* project began, approximately a year after the entertainment version was completed, we realized the underlying gesture products were no longer supported and were difficult to train with new gestures. We found no alternative products that would meet our needs, so we decided to build an intuitive gesture creation system so medical professionals could create custom therapy exercises. The novelty of Spellcasters lies in this custom rehabilitative gesture system we have designed, described in Section 5.4.1. Around the same time, we met with industry leaders developing specialized VR hardware for physical rehabilitation that required the additional processing power of Unreal Engine. To keep future potential partnership opportunities open, we chose to rebuild a rehabilitation version of Spellcasters in Unreal Engine—creating a custom gesture system and removing the competitive multiplayer features from the original game (for now). Reusing design documents, art styles, media, and drawing inspiration from the entertainment version of the game made development much smoother—even in a new game engine. Our focus turned to making *Spellcasters* medically vetted while the pandemic made participatory work with stroke survivors unsafe. To this end, we worked on designing and implementing the gesture creation system and an accessible spell-casting experience. We left the game world an open sandbox so stroke survivors could inspire future development directions when participatory work is safe or when teleconferencing tools become more accessible.

We have access to the full source code through the serious games masters program at the University of California Santa Cruz—a rare opportunity which we discuss in Section 5.6. The onset of transitioning the game for therapy purposes began with obvious accessibility updates based on heuristics [297] and tacit knowledge from the research team, including simplified and more legible user interface elements and multimodal audio, visual, and haptic feedback. For example, instead of a text-based menu, we created a magical office space where virtual objects represent the menu options (e.g., wizard hats for jumping to various levels and a magic spellbook with game options, such as audio settings and accessibility feature toggles). Another example is the addition of the fairy companion, a guide who contextually gives instructions and hints via subtitled verbal instructions. We reduced the amount of text, made text larger, and offered alternatives to text in the form of contextual cues and instructions given by the fairy companion, who serves as a guide in the game. Early in the process, we began interviewing physical therapists and occupational therapists working with stroke survivors to collect functional requirements for the core therapeutic spellcasting mechanic. The medical professionals wanted the ability to create custom spell gestures for the idiosyncratic needs of their patients with 6 degrees of freedom (Section 5.4.1; Related to: *RQ1*), the ability to set which hand is used for casting for patients with hemiparesis and isolate movement (Section 5.4.3; Related to: *RQ1*), the ability to play seated or standing for safety (Section 5.4.3; Related to: *RQ1*, *RQ3*), and the ability use data-driven insights to customize rehabilitation curricula, insurance reports, and manage patients (Section 5.4.5; Related to: *RQ2*, *RQ3*). Many of these requirements echo the framework presented by Saini et al., including varying levels of difficulty, precise direction, display feedback, and time limitations [255]. A playable build of *Spellcasters* can be found at `https://tinyurl.com/Spellcasters-Build`.

FIGURE 5.1: Process of creating custom exercises for stroke survivors as magical spells in a virtual environment including sphere placement, reward selection, and repetition setting.

FIGURE 5.2: Screenshot of how spells can be customized in Spellcasters by clinicians using scale and depth

FIGURE 5.3: On the left, a screenshot of the spellbook with goal progress, and to the right, the contextual support of the non-player fairy character, subtitles, and video pop-up demonstrating the mechanic

5.4.1 Custom Gesture Creation

We developed a novel custom gesture creation system that allows clinicians to create exercises in the form of 3D-enabled magical spells. These spells can be customized using an intuitive point and click mechanic capable of recording therapeutically relevant variables, including scale, shape, direction, and depth, depending on the motion the clinicians want the patient to perform (depicted in Figures 5.1 and 5.2). For example, a clinician may design a small circle by placing the spheres close together—useful for wrist rotation exercises. In contrast, a larger circle would require the stroke survivor to use their whole arm for an external rotation exercise. This feature gives clinicians creative freedom and endless possibilities for designing and customizing their gestures. To create a spell, a clinician must decide and place a series of collision spheres, which creates a specific shape. The order in which the clinicians place the spheres determines the sequence in which the stroke survivor needs to connect them to complete the gesture (Shown in Figure 5.2). The clinician can set repetition counts of these gestures and what this spell does for patients (Shown in Figure 5.1). Each spell effect helps provide a sense of purpose to each patient's successful attempt to perform a gesture. It also shows the patient's progress during the session as one can see and count the number of trees or flowers a patient might have planted by the end of the session. These repetition counts are shown on the spellbook value, indicating how many times the patients need to do them successfully, shown in Figure 5.3.

Using a participatory approach during our design sessions with medical professionals, we co-designed a set of predefined gestures that *Spellcasters* will support by default. The resulting 18 predefined spell gestures include a horizontal line, vertical line, diagonal line, rectangle, square, triangle, semi-circle arcs, circles, and infinity symbol. Medical professionals helped us inductively sort these gestures into relevant non-mutually exclusive themes, including 'Extending Arm,' 'Rotation,' 'Internal Rotation,' 'External Rotation,' 'Crossing Mid-line,' and 'Raising Arm.' This design feature is related to *RQ1*. The spellbook, shown in Figure 5.3, is stocked with these predefined spells and displays a subset of relevant themes.

5.4.2 Gesture Tracing

FIGURE 5.4: Screenshot of Spellcasters, stroke survivors perform exercises by tracing magical spells in a virtual environment

FIGURE 5.5: Screenshot of rewards in Spellcasters that clinicians can assign for each spell for stroke survivors, who will get confetti and fireworks on completion of a set of exercises

For a player to cast a spell, they begin by flipping through pages of the spellbook until they find one they would like to cast—the active spellbook page signals to the custom gesture recognition system, which guides the player on how to trace the shape that appears in front of them. Tracing the spell requires the stroke survivor to point their wand and contact the depth-sensitive spheres in the correct order. Using a participatory approach, we co-designed an initial set of user experience features to make gesture tracing accessible to the stroke survivor, including haptic feedback for when the player starts to veer off the path, spheres that indicate order by growing and shrinking as the player progresses through the points, thick green lines with arrows between the points to illustrate the 'target threshold zone' and direction, verbal feedback from the fairy, sound effects for successful and failed attempts, and a tracking line that visually traces the stroke survivor's path from the tip of the wand. Many of these features can be seen in Figures 5.3 and 5.4. Additionally, we created contextual videos that pop up and demonstrate to players the various aspects of the spell-tracing mechanic, shown in Figure 5.3. Once the gesture is successfully traced, patients can cast the spell by pressing a button to point and shoot at a given location. If the patient wants to cast the spell somewhere other than where they are located in the scene, they can press a button to teleport to the desired location and then cast the spell. For patients who do not wish to use the teleportation mechanic, some spells summon the various creatures they can interact with, so *Spellcasters* can be experienced completely from one location. Before participatory work with stroke survivors, some preliminary spells included summoning plants and trees to decorate the garden, animal summoning spells, spells to feed animals, and animal interaction spells such as a ball to play fetch with the dog. A new spell is required for every interaction to encourage players to repeat the therapeutic motions. Figure 5.5 shows some of the current possible spell outcomes and the reward system's confetti particle effects when a complete set of clinician-set repetitions is completed.

The spellbook keeps track of whether the patient has completed a gesture successfully or not. When a sphere is skipped or not connected correctly, the attempt will be recorded as an incomplete attempt. If the patient is not moving for a while, the game plays a sound to inform the player that the spell is timed out, the traced line turns red, the controller provides haptic feedback, and the attempt is logged as incomplete. However, the game allows the patient to continue tracing after hearing the 'incomplete' sound effect. In such a case, if the patient connects the spheres in the correct sequence, it will be recorded as a successful attempt.

5.4.3 Isolated Movement Therapy

Strokes often co-occur with hemiparesis, affecting one side of the body [247], so providing the option to play the game with either hand is essential. Stroke survivors may first play with their stronger arm when initially learning the mechanics. The spellbook has a swap hand button to quickly move the wand to either side without swapping game controllers.

As discussed in Section 5.4.1, some spells, such as the wrist rotations, should be performed without moving the shoulder or elbow, so we include a feature in the companion app (Described in Section 5.4.5) that allows medical professionals to pre-record messages and instructions that will remind patients to isolate their movements or remind them not to use a compensation strategy.

5.4.4 Levels

Spellcasters provides two different tutorials: One for the medical professionals and one for the stroke survivors. The tutorial for the medical professionals provides a walk-through of creating a custom spell gesture and the gesture-tracing mechanic that the stroke survivors will use. The gesture-tracing walk-through is beneficial for medical professionals because it allows them to test their spells and ensure they are appropriate for individual stroke survivors. *Spellcasters* is designed with multi-sensory feedback (including haptics) to be more accessible to stroke survivors who may have co-occurring disabilities such as vision or hearing impairments. The built-in nonplaying character, the fairy, uses closed-captioned dialog to support accessibility. The soundscape is highly customizable, so players can independently adjust the dialog, background music, audio cues, and sound effects. The accessibility features were iterated throughout the playtesting process. For example, the pop-up video tutorials demonstrating the various mechanics were introduced after our ninth participant.

Beyond both tutorials, there are two sandbox levels: One that allows players to maintain a forest garden and one with animals that the player can interact with. The rationale behind separating the levels is to provide one experience with less sensory overload. The second level allows the player to feed animals, play, fetch, call the animals, and pet the animals.

5.4.5 Companion App

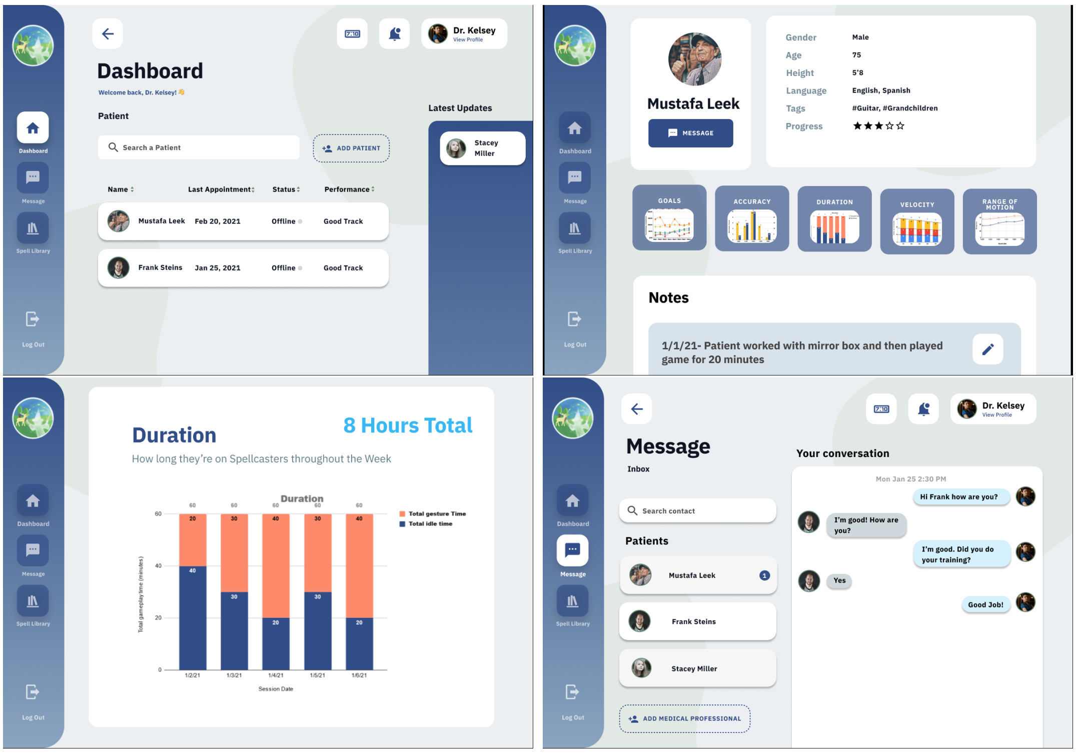
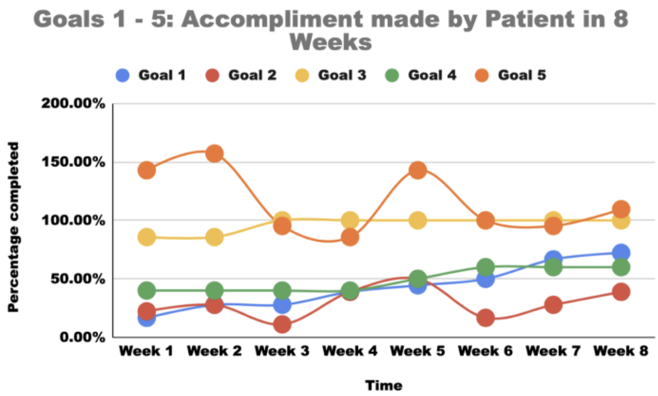


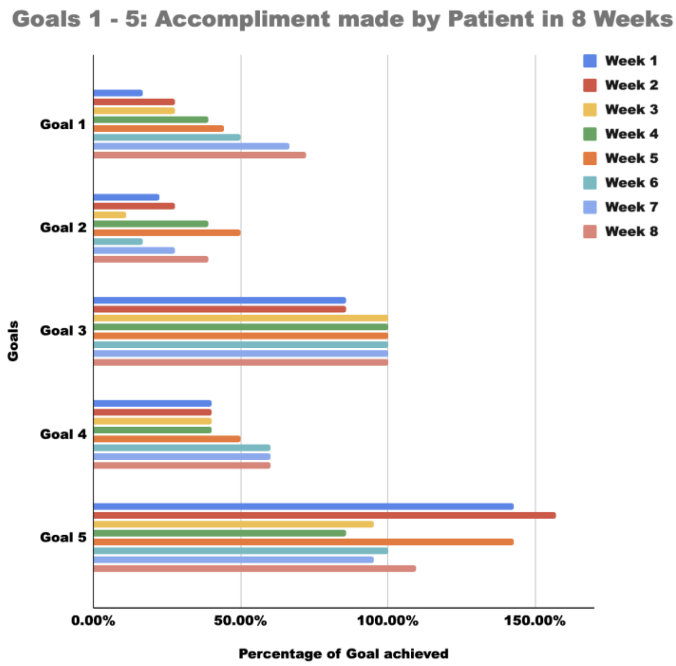
FIGURE 5.6: Screenshots of companion web app prototype.

As the playtests and co-design sessions progressed, it became clear that it would not be convenient for medical professionals to access logs, reports, and patient management tasks within VR due to the (lack of) affordances for text entry. Additionally, a busy medical professional is less likely to wear a headset for quick adjustments than logging into a web app. Therefore, we rapidly iterated on the design of a companion web app using Figma for medical professionals to remotely control the game client, see data visualizations, generate reports, share resources with other medical professionals, and manage patients. The first Figma prototype can be found online[9]. The final version can be seen online[10]. To facilitate rapid iterations of the companion app, we used dummy data to populate the prototype. Based on how clinicians guide us on what graphs are shown and how they are formatted, we can update Spellcasters to provide appropriate data to replace the dummy data in the deployed product.

We worked closely with participants to make intuitive data visualizations. These visualizations track variables such as accuracy, velocity, time spent in-game doing exercises compared to time spent doing other activities, and range of motion. These visualizations and the overall design of the prototype were updated between each participant using a cascading iterative protocol. We provided two versions of the same visual in many iterations—the original and the updated one based on the previous participant's feedback—and asked the new participant to choose between them. The updated visualization was always chosen. The trickiest visualization we finalized was the goal-tracking graph, which represents goals that are both set in the game and external stroke rehabilitation goals. For example, an in-game goal might be to achieve a certain accuracy percentage or number of repetitions, while an external goal might be to walk a certain number of steps or cook a certain number of meals—all goals must be quantifiable to graph. Our original goal visualization was a spider graph, but many participants had never seen one

[9] `https://tinyurl.com/SpellcastersCompanionLowFi`
[10] `https://tinyurl.com/SpellcastersCompanionHighFi`





Raw

	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5
Week 1	3	4	6	4	30,000
Week 2	5	5	6	4	33,000
Week 3	5	2	7	4	20,000
Week 4	7	7	7	4	18,000
Week 5	8	9	7	5	30,000
Week 6	9	3	7	6	21,000
Week 7	12	5	7	6	20,000
Week 8	13	7	7	6	23,000
Goal	**18**	**18**	**7**	**10**	**21,000**
Average	7.75	5.25	6.75	4.875	24,375
Goal Completion	43.06%	29.17%	96.43%	48.75%	116.07%

FIGURE 5.7: Example Goal visualizations in Companion Web app.

or did not find them intuitive. In the end, we included a primary multi-line graph that provides an overview of how close each goal was met week-by-week as well as a stacked line graph that breaks down each goal and a table with raw data, shown in Figure 5.7.

Clinicians can also write notes and set reactions to inform and motivate patients. Clinicians have access to various spells created by themselves or other clinicians, helping them reduce the need to create them frequently. They can assign these to their patients along with repetition counts.

5.4.6 Usage and Setting

While *Spellcasters* takes place in a VR environment that provides an immersive experience for stroke survivors to practice depth-sensitive gestures, a concerning drawback of VR HMDs is that they wrap around our eyes, inhibiting users from seeing the real world. To reduce the chances of experiencing motion sickness and increased safety, stroke survivors can play while sitting in a chair, and the game's teleportation mechanic is not required to play. For example, we created spells that call distant animals to the player location. However, we have also enabled teleportation in the game so players can move around in the world if they wish, without needing to leave their chairs or get motion sick. Stroke survivors can also play while standing in one location—the gesture system will adjust to their standing height. Given the immersive nature of VR, clinicians have confirmed their interest, during our interviews with them, in using *Spellcasters* primarily in a supervised environment such as a rehabilitation facility. Once stroke survivors have made enough progress, defined and measured by their clinician, they can use *Spellcasters* as an at-home rehabilitation tool, possibly under the supervision of a caretaker, which we discuss in Section 5.5.3.

Another design consideration for choosing VR is the hardware cost and the prevalence of availability in rehabilitation clinics and homes. While VR is expensive hardware, the cost of consumer devices is continually becoming more affordable. For example, at the time of writing this, the Oculus Quest 2 is a standalone headset that supports hand tracking [298] and is powerful enough to run Spellcasters—available for $299. The headset does not require an expensive VR-ready computer, does not need complicated tracking towers, and is a standalone, ready-to-use device. The hand-tracking features that are becoming available are valuable alternatives for stroke survivors who cannot hold a controller or do not have the dexterity to use the buttons due to the higher System Usability Scale (SUS) of hand tracking [298]. We argue that the cost of these devices is a worthy investment in an expensive healthcare climate.

5.5 Results

For each of the 14 cascading iterative Research through Design [2, 161] sessions, we began with a semi-structured interview, followed by a playtest, and then a semi-structured design debrief to get feedback and iterate. Summaries of all the responses and transcriptions are included in the `https://tinyurl.com/Spellcasters-Supplementary`. We share qualitative quotes from these sessions in the relevant sections below as they relate to our research questions. The follow-up survey responses are also available in the supplementary materials, and the outcomes are presented in the following sections, organized by their related research questions.

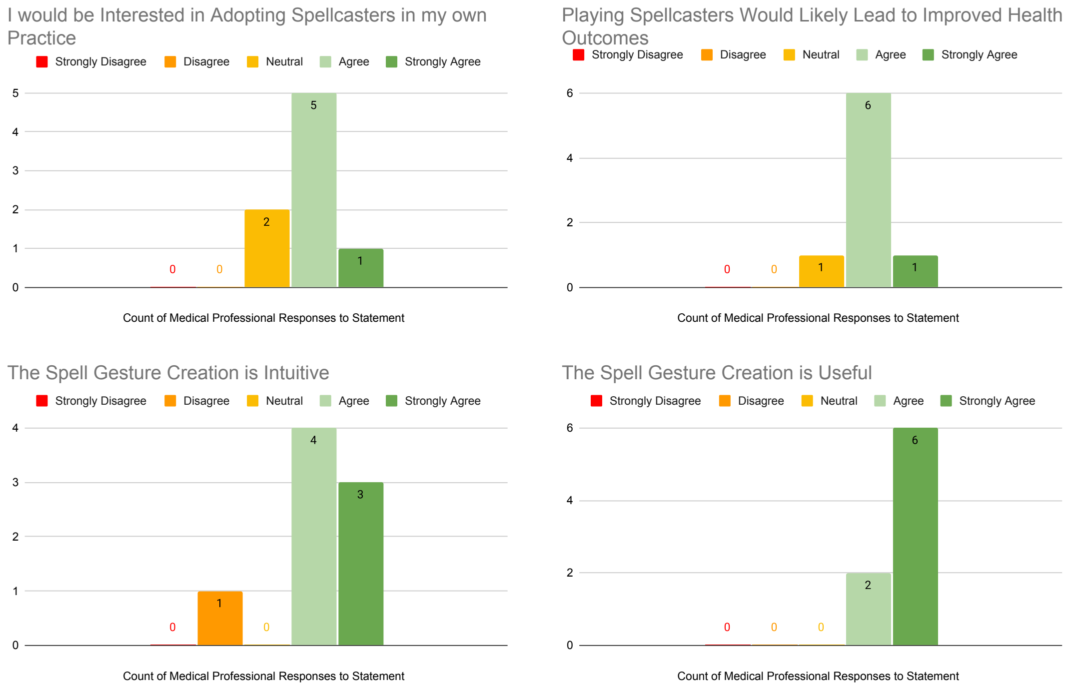


FIGURE 5.8: Results related to *RQ1* including exercises that should be supported, interest in adopting *Spellcasters*, the likelihood of the game leading to improved health outcomes, intuitiveness, and usefulness of the gesture creation system using 5-point Likert scales of degree on the agreement to statements

5.5.1 Spellcasters (*RQ1*)

Throughout the iterative process, *Spellcasters* was updated to include recommendations made by medical professionals, including adding arrows to the gestures to make the direction of tracing clear, the inclusion of larger shapes for a range of motion exercises, and inclusion of small shapes for wrist exercises. While some clinicians prefer more presets to save their time, all clinicians found the custom gesture creation useful, as can be seen in Figure 5.8. Clinicians were excited about the ability to add depth to the gestures, citing its usefulness in many different exercise contexts: "I feel like you got everything covered—crossing the midline, shoulder rotations, extensions, etc.” (P11), "I think it is complete—I do not have anything else that I would want to customize" (P10), and "Yeah, I think that is fantastic because you can do as small and as big as you want to make the patient do." (P6). Clinicians found the game format appropriate: "I think there is a lot that can be done with it. I think my patients are going to want to try it" (P6), "I think people would like to have this in their toolbelt to make therapy more exciting" (P3), and "It is like playing a game—they would get excited' '(P13). P1 suggested we make the game support multiplayer. In terms of usability and accessibility, P6, P8, P10, P12, and P14 are concerned with some stroke survivor's ability to hold the controller or press the trigger button, which is why we will use the hand tracking feature in the Quest 2 for future testing with stroke survivors. P11 said, "I love the affirmations that you added. I like the fireworks and confetti. I think the spellbook looks good—I feel like it is readable and I can understand what is going on", and P14 suggested numbering the spheres. All 14 medical professionals mentioned that Spellcasters is a potentially valuable tool for other populations, including pediatric populations and those with spinal cord injury.

5.5.2 Companion App (*RQ2*)

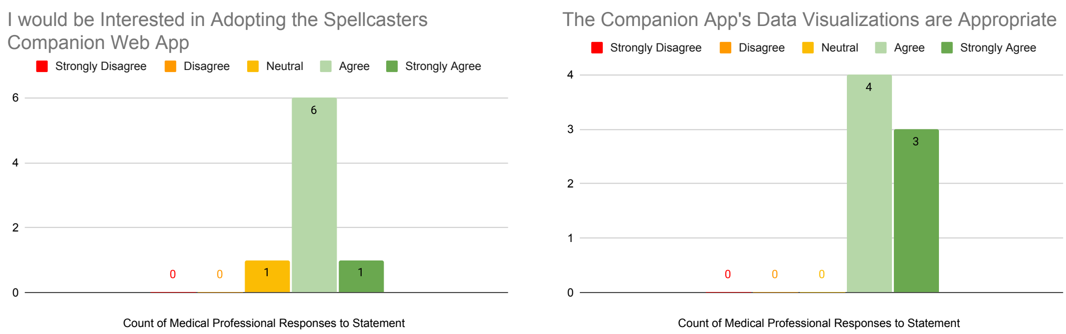


FIGURE 5.9: Results related to *RQ2* including interest in adopting the companion web app and its data visualizations using 5-point Likert scales of degree on the agreement to statements

As sessions progressed, it became clear that an external tool would be helpful to clinicians to manage their patients and track their progress. The development of the companion app was prompted by P8, who said, "We only have 45 minutes with the patient, so we cannot really spend 15 minutes creating the exercises—have more presets, and a save feature so we can reuse exercises". All but 1 clinician who interacted with the companion app stated they would be interested in adopting it into their practice, shown in Figure 5.9. Our initial low and high-fidelity prototypes can be found in the supplementary materials, which illustrate rapid iterations and improvement based on clinician feedback.In the end, all clinicians found the visualizations appropriate, which can be seen in Figure 5.9. Beyond the visualizations, a reoccurring theme was that fast, easy-to-digest facts were preferred (e.g., P14 said, "I cannot spend much time looking at graphs, so a quick stats interface would be better"). There were many iterations on the mock data visualizations, such as for P11, who had never seen a spider/radar chart before, so we changed it to a grouped bar graph, which was clear to the following participants. Bar graphs were, by far, the preferred format.

5.5.3 Telehealth (*RQ3*)

Telehealth has become an even more critical part of our healthcare system today due to COVID 19. Based on our conversation with clinicians, we found that none of them have used any telehealth games or applications beyond video conferencing tools and assigned videos (P4) due to a lack of options. The software clinicians mentioned they currently use include *Bluestream* (3 mentions), *Zoom* (1 mention), and *Doxy.me* (1 mention). Clinicians typically use this software to watch their patients remotely on a screen and provide them with instructions. Observation through a screen is problematic because, like one participant stated, "It is much harder to get people to do telehealth with its current technology—they need many other cues than the limited visual and audio cues we have now" (P3). Because of the limited set of activities they can do while remote, clinicians have suggested that patients have been eager to go back to their traditional in-person system. Four clinicians had never provided care through telehealth and continued to offer in-person care during the COVID-19 pandemic. P8 serves many patients from a lower socioeconomic status and is concerned with telehealth because of their limited

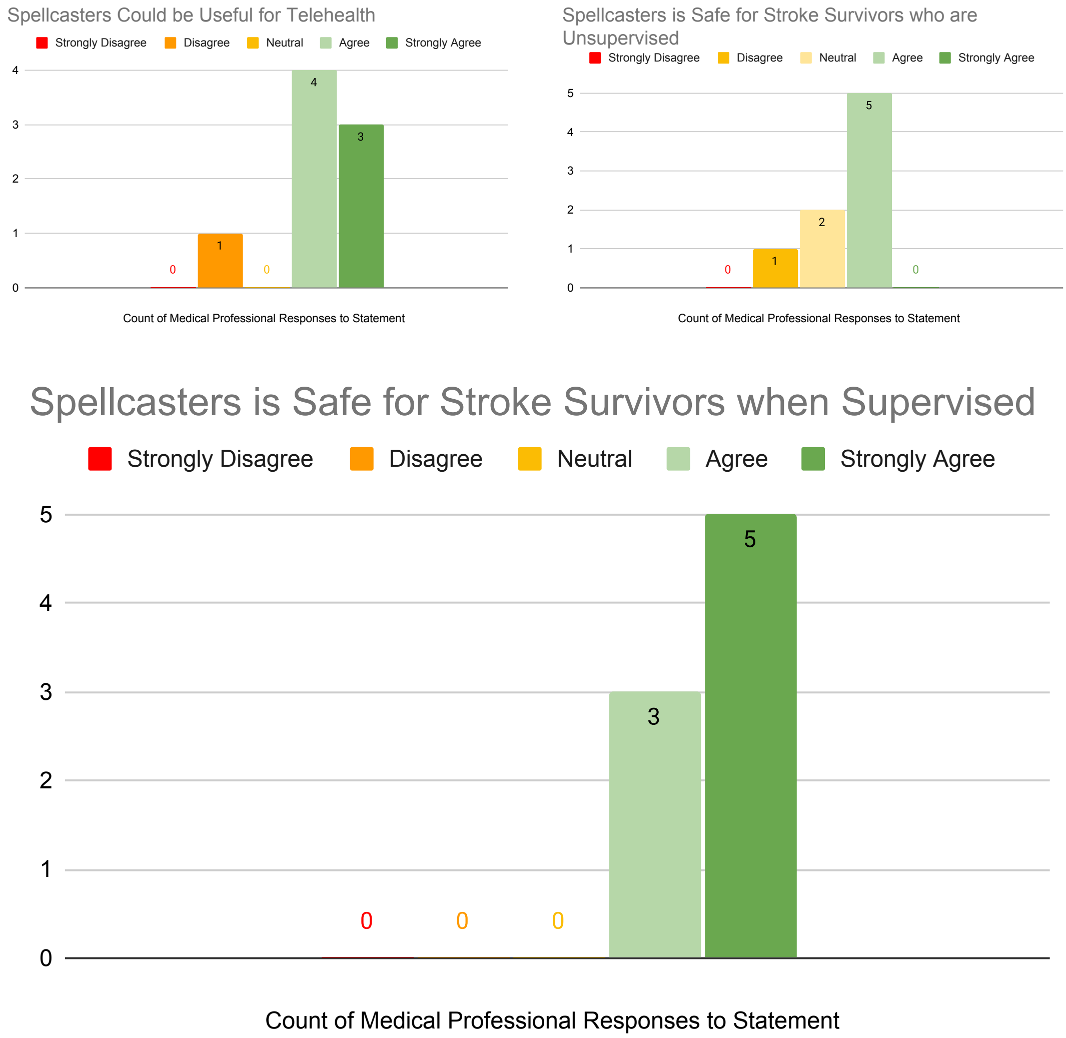


FIGURE 5.10: Results related to *RQ3* including usefulness as a telehealth solution and the safety of using the game while supervised vs. unsupervised using 5-point Likert scales on the degree of agreement to statements

access to good digital resources. These conversations confirmed our agreement with our institutional ethical review board—we need to wait to work with stroke survivors until after the vaccine is widely administered or after teleconference tools are made more accessible.

Spellcasters has the potential to serve as a telehealth option as access to VR becomes more common—and clinicians tend to agree that *Spellcasters* could be useful in this context (shown in Figure 5.10). P5 indicated that "If *Spellcasters* can help them stay more consistent with their program, then sure—really consistency is the name of the game, so anything that can help somebody be more consistent is going to be a win." P3 said, "I believe that if you can tie it to patient adherence, then you can correlate that to improvement—and that goes to taking it at home with you and doing it more often." Safety was one of our primary concerns because, in the home context, stroke survivors may be practicing without a medical professional being present, but as can be seen in Figure 5.10, medical professionals tend to believe the game would be safe (more so with supervision). Many indicated this is due to the ability to play the entire game while seated.

5.6 Reflection

In this section, I begin by discussing our autoethnographic insights [299] about converting *Spellcasters* from a pure entertainment game into a serious game for health for stroke rehabilitation. Next, I present our interpretations on the three research questions that drove our Research Through Design iterative process [2, 161]. Namely, the importance of being able to customize therapy mechanics for the personal needs of stroke rehabilitation, the potential benefits of using game telemetry to inform scalable and equitable data-driven healthcare solutions and games as an option for future telehealth opportunities, which is particularly relevant in the wake of COVID-19. Finally, we discuss the limitations and future directions of our work.

5.6.1 Converting Entertainment Games to Therapy Games

At the project's onset, I was hopeful that converting an entertainment game into a serious game for health would reduce development time and offer some promise for translating mechanics already proven to be fun and engaging. The team ultimately redeveloped the game from the ground up and drastically altered many original core features, including the multiplayer magical duels, and created an entirely new gesture system. Still, the time and effort were significantly reduced than if we started from scratch because the shared vision was clear from the onset. However, these changes come with some inherent risk: the original qualities that made the original Spellcasters fun could be lost in translation. Some of the old features, namely the multiplayer competitive experience, may come back based on future design work with stroke survivors (or they might lead us down an entirely different path). Because *Spellcasters* is an open sandbox world, I now have an opportunity to co-design with stroke survivors using the simple spell-casting mechanic to afford a multiplicity of design directions—from a narrative adventure to multiplayer duels to tending magical gardens. Most of our investment, and the main novel contribution of this work, is the intuitive custom rehabilitative gesture-creation system paired with a companion app, which could be extended to support many different domains other than a magical world if stroke survivors show interest during future participatory design sessions. To provide this essential resource to stroke survivors as quickly as possible with the restraints of the pandemic, we chose to draw inspiration from an existing entertainment game rather than use participatory design with stroke survivors. While the gold standard would have been to enlist stroke survivors as co-designers at the onset, the COVID-19 pandemic restricted our options, so we chose to investigate this higher research question of whether there is value in repurposing existing entertainment games into therapy games. While this work cannot thoroughly answer this more meta-level question, my experience was that the shared vision and available resources (existing source code, design documents, aesthetic style, existing mechanics) made development much more time-efficient than exploring many possibility spaces. Our results from clinicians are promising in that they believe stroke survivors will love the magical world and spell-casting domain.

5.6.2 Custom Therapy (*RQ1*)

Healthcare does not follow a "one shoe fits all" model—everyone has individual goals, needs, abilities, and preferences [300]. Stroke medical professionals employ numerous strategies for motivating their patients based on their patient's health, environmental factors, and personal factors [301]. The primary mechanic in *Spellcasters* is making gestures to cast spells—and one of our primary contributions in this work is designing an intuitive gesture-creation system that medical professionals can use to customize *Spellcasters* for their patients. From the feedback we collected, this is by far the most valuable feature in the game (Section 5.5.1). The gesture-creation system is also where most of the development effort went. We prioritized this mechanic because we believe the core mechanic in a serious game for health is central to the success of the game—it should be accessible, customizable, lead to improved health outcomes, intuitive, engaging, and data-driven—a tall order. We plan to work with stroke survivors in the future to ensure it is genuinely accessible, intuitive, and engaging.

5.6.2.1 Future Work

As discussed in Section 5.3.4, *Spellcasters* currently follows an overly clinical model because we have not yet incorporated input from stroke survivors. We have made *Spellcasters* customizable from the perspective of clinicians (which is very important), but therapy should also be customizable from the players' perspective. A research question that will drive our future work is: *How can Spellcasters holistically support stroke survivors?*

5.6.3 Companion App (*RQ2*)

Companion apps create added value towards long-term engagement in games for health because they can enable visualization of progress and medical information, increase the perceived value of compliance with sustained use, and help embed the training routine in daily practice [302]. As the iterative design process progressed with *Spellcasters*, it became clear that medical professionals were interested in quantitative insights and data visualizations from the game but did not think it would be convenient to wear a headset and launch the game to access them. Additionally, the affordance of VR is not as suitable for patient management as traditional web browsers. Once we introduced the companion app Figma prototype, medical professionals were highly enthusiastic (Section 5.5.2). Instead of focusing on the app's actual implementation details, we were primarily focused on designing the data visualizations, information organization, intuitive navigation, and desired features the companion app would support—Figma was highly effective because we could rapidly iterate between each session.

5.6.3.1 Future Work

Medical professionals were highly interested in community-based sharing of sets of spell gestures and communication with their patients within the game. We think the social affordances of a companion app for serious games for health are highly interesting. A 2-part research question that will drive our future work is: *How do social affordances in the Spellcasters Companion app affect the gameplay experience and relationship between stroke survivors and their clinicians.* We plan to study the impact of the companion app on the gameplay experience and relationships with clinicians by conducting a comparative study where one group of stroke survivors has access to the companion app while another does not. Each group would take a player experience inventory [303] and an inventory on the clinician-patient relationship [304] for comparison.

A benefit to using serious games for health is the added ability to collect rich data using game telemetry [271]. This data can train machine learning models to better support players by predicting when they need support, more accurately sensing their therapy-based mechanics and standardized metrics for developing a therapy curriculum. We are interested in exploring how machine learning can support stroke survivors who play *Spellcasters*. A research question that will drive our future work is: *How can machine learning support stroke survivors who play Spellcasters.*

5.6.4 Telehealth (*RQ3*)

Many medical professionals are becoming experts at meeting with their patients remotely—our first participant, without prompt, said he needed to optimize his screen share in Zoom for videos, indicating that he was well-versed with the software's advanced features. While telehealth has been around for almost 50 years [305], the COVID-19 pandemic has created an explosion of need for more telehealth options [272]. Most medical practitioners felt *Spellcasters* would be useful and safe in a clinical setting because the stroke survivor would be supervised (Section 5.5.3). However, a few of the participants indicated that they are hesitant to recommend *Spellcasters* for at-home use while unsupervised. If a stroke survivor injured themself, there might not be anyone around to respond. It helps that *Spellcasters* can be played while seated, but more work remains into investigating how safe VR is for unsupervised stroke survivors (and if the game will require a supervisor).

5.6.4.1 Future Work

Based on our literature review (Section 5.2), we believe that telehealth options will remain an integral element to healthcare even beyond the COVID-19 pandemic and that *Spellcasters* has many qualities towards becoming a telehealth solution. We plan to continue designing *Spellcasters* with stroke survivors. After the game is complete, a research question that we will investigate is: *Is Spellcasters safe for at-home stroke rehabilitation?* Whether or not *Spellcasters* is played primarily in clinics or at home, we plan to conduct a longitudinal study to evaluate the efficacy of the game for improving rehabilitation outcomes.

5.6.5 Limitations

COVID-19 directly influenced our procedures for co-designing and evaluating *Spellcasters*, adding limitations to our work. The three primary limitations of our work are the exclusion of stroke survivors, the limitations of running a remote protocol with varying access to VR systems, and aggregating evaluations of a design that was constantly being iterated on and changing. Until the vaccine for COVID-19 is widely distributed, our institutional ethics review board and we agree that it would be unsafe to include stroke survivors as participants in the research both in-person and remotely (due to accessibility concerns). We worked exclusively with medical professionals for this contribution as a precursor to participatory work with stroke survivors when it is safe to meet in person again. Ideally, each of our participants would have experienced *Spellcasters* in VR, but only three of them had access to the hardware. We did not ship VR systems with *Spellcasters* installed to each participant due to resource constraints, logistics of shipping back and forth, and risk of transmitting the COVID-19 virus. While it was not ideal, the remote sessions where we demonstrated the game by screen-sharing were still productive and led to valuable insights. The nature of Research through Design [2, 161] is iterative and results in a continually-changing intervention as feedback is incorporated into the game and companion app. Therefore, when we asked participants to evaluate the design, they saw a different version of the design than the next participant, limiting the reliability of aggregated results. The post-survey included a trailer with the updated design of the game and a link to the companion app so participants could see the final design. Our results were generally positive, and we believe they offer some value for presenting our contributions.

5.6.6 Affordances of Virtual Reality

One of the limitations of iVR is that current sensing abilities limit physical rehabilitation to upper limbs. However, some available trackers can be attached to more body locations [306, 307] for more accurate and thorough tracking. We chose not to use them because of the additional costs, accessibility concerns, and pragmatic constraints of conducting a remote protocol. New commercial iVR hardware is beginning to support more lower-extremity tracking using the headset, and we are interested in exploring using this with *Spellcasters* in the future when the technology is widely available. Right now, *Spellcasters* can run on Oculus Rift, Quest (with link cable), and HTC Vive. Each of these devices needs to be connected to a Windows computer to operate. We are interested in eliminating this barrier by porting the game to wireless VR headsets to make Spellcasters more accessible and cheaper to adopt.

5.7 Conclusion

In this chapter, I present the design of a novel serious game for health and a companion app for stroke rehabilitation, called *Spellcasters*. I provide an autoethnographic reflection of converting a game originally designed for entertainment into a therapy game. I share results from co-designing and evaluating our software with 14 medical professionals using a remote Research through Design protocol. I found that the ability to customize the primary (therapy) mechanic was the most valuable game feature to support therapy. I share the design of the *Spellcasters* companion app that is rich with tacit design knowledge about the types of data visualizations that would be useful to medical professionals and how they should be intuitively communicated. I describe the implications of our software towards a potential telehealth solution for stroke rehabilitation, including patient management and community-based sharing of spells. The contributions of this work include novel artifacts, insights into designing serious games for health, and implications for scalable and equitable telehealth solutions.

5.8 My Role

I led the research of Spellcasters and directed the necessary accessibility improvements and features that would make the game appropriate for use by stroke survivors. I oversaw the design of the companion app and data visualizations. Listed below are the developers and subject-matter experts that enabled this work.

Developers: Rutul Thakkar, Junhao Su, Amy He, Delong Du, Dongbo Liu, Erica Li, Janelynn Camingue, Ethan Osborne, Wenbo Wu, Leili Shen, Max Cronce, Kassandra Chin, Sherry Luo, Yiming Zhang.

Subject-matter experts: Michaela Sandock, Carter Mcelory, Michael John, Magy Seif El-Nasr, Elin Carstensdottir, Katelyn Grasse, Joaquin Anguera, Pedro Cori.

Chapter 6

Cirkus

6.1 Introduction

In this chapter, I present Cirkus, a wearable technology probe that supports many animal locomotion games. Cirkus was developed with the intention of dually co-designing animal-themed games with children with Sensory Based Motor Disorder (SBMD) while also collecting movement data for participatory machine learning. The Cirkus probe affords nearly any animal-movement-themed game children can imagine and, therefore, exists towards the play side on the Serious Play for Health spectrum. Additionally, the app lives in the middle of play-first approaches and therapy-first approaches because it explores the use of circus arts to help children with SBMD. However, the motivations of this work lie outside of the medical model. Improving one's condition comes second to—and is a side effect of— fostering an appreciation for practicing the circus arts. An integral step for machine learning is the collection and tagging of data for training the model, but this process is often the source of biases, of issues in transparency, and of misrepresentative use cases. In this work, I explore using participatory practices to playfully and transparently collect movement data from children with SBMD. In collaboration with the largest circus group in Sweden, I ran a series of five workshops with 30 children total and co-created six games using Cirkus. I share the resulting machine learning model and a catalog of 17 games compatible with Cirkus. I discuss challenges of collecting data for machine learning from children with disabilities and broader implications of the use of machine learning for therapy games. I speculate on how machine learning can be included in designs that serve the population rather than have (potentially ableist) utilitarian goals. The contributions of this work include:

1. A novel design probe that supports co-designing movement-based games and collecting movement data using participatory methods
2. A machine learning model that is based on data from children with SBMD
3. A case study of collaborating with children and circus professionals in the design of technology

6.2 Background

Children with SBMD experience difficulty coordinating their brains and their bodies due to combinations of postural disorder and dyspraxia [308], discussed further in Section 6.2.1. They are often stigmatized as the "weak" or "clumsy" kids, have limited social networks, and spend less time with friends [309]. Children with SBMD benefit from exercise and physical training because they develop skills and strength to overcome the disorder, but exercise and physical training can be tedious and repetitive—play as the basis of sensory integrative therapy is a proven intervention for SBMD [309].

Cirkus is situated within a larger research project that partnered with the largest circus group in Sweden. Prior to the development of Cirkus, researchers and circus professionals ran circus training classes for children with SBMD, featuring technology probes [310] that support the training activities[245]. For example, researchers designed a "Tilt Belt" worn around the waist while tight roping. The belt would vibrate along the horizontal plane when the wearer leaned and a "blower" would promote deep breaths while exercising. The success of this project prompted the development of Cirkus to provide support for at-home play and practice. Rationale for employing the circus arts as an intervention for SBMD are presented in Section 6.2.2.

The potential benefits of this research are the development of therapy games that promote being physically active, pro-social, less screen-centric, and use more participatory machine learning practices. I begin by providing an overview of SBMD to make the argument that circus arts are an appropriate domain for improving this population's condition. Next, I outline some of the relationships between machine learning, disability, and participatory practices that motivate this work.

6.2.1 Sensory Based Motor Disorder

Sensory Based Motor Disorder is a category within Sensory Processing Disorder (formerly termed Sensory Integration Disorder), which has symptoms present in around 16% of the population [308]. People with SBMD sense information from their sensory, movement, and positional systems (vision, auditory, touch, olfaction, taste, vestibular, and proprioception) normally but it is perceived differently [309]. These differences are encompassed by two sub-types: Postural disorder, which reflects problems in balance and core stability, and dyspraxia, which encompasses difficulties in motor planning and sequencing movements [309, 311]. In simpler terms, children with SBMD receive information from their central nervous system, but their brain have trouble integrating this information into responses and experiences. Having SBMD can affect participation in functional daily life routines and activities [309]. Sensory Based Motor Disorder is often co-occurring in children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder [309]. Studies have reported that between 40% and 80% of people with ADHD also have a Sensory Processing Disorder, such as SBMD [311–313].

6.2.2 Circus Arts as Physical Therapy

Circus encompasses numerous types of activities, including acrobatics (e.g., balances, gymnastics, handstands, tumbling), aerials (e.g., silks, Lyra hoop, hammock), and equilibristics (e.g., juggling, tight rope, unicycle). Circus arts embody the qualities necessary to improve skills related to improving the SBMD condition. In past research, *Circus Arts Therapy®* and play therapy have shown significant benefits in physicality and interpersonal skills within the context of a clinical study [314]. A benefit to circus over traditional sports is that rather than having traditional winners and losers, circus is about individual skill building while cooperating with others, not competing against them [315]. Additionally, Bolton argues children need to dream, take risks, learn trust, and show off, which circus affords [315]. Circus is a catalyst for physical, emotional, and social learning [314, 315]. Circus activities promote physical health, balance, and coordination [314]. Circus as therapy leads to improved social connectedness, teamwork, a sense of belonging, and provides calming rhythmic activities [316]. Circus has been forecasted to have a social return of investment and leads to improved mental health [317].

6.2.3 Machine Learning and Disabilities

When designed well, games and play have the power to improve health outcomes [85, 318]. Ranging from physical therapy [94], to speech therapy [192], mental health [319–321], pain management [322, 323], and medication adherence [324], games move us forward. Over the past decade, machine learning has become more common in the domain of serious games for health [150–152] promising greater scalability, reduced costs for healthcare, increased access to services and relevant information, customizable experiences, and more accurate benchmarks for comparison. However, therapy games that use machine learning and artificial intelligence are also susceptible to the many follies of machine learning, including issues of biases, transparency, accountability, and misrepresentative use cases [10, 153, 154]. Machine Learning is normative [155], which often unfairly affects special populations such as those with disabilities and children [10, 156]. The most common source of problems related to machine learning stem from how the data is collected, used, and tagged for training the models causing biases, including measurement bias, omitted variable bias, representation bias, aggregation bias, sampling bias, algorithmic bias, user interaction bias, as well as many others [157]. Applying participatory practices to the data collection, tagging, and design of the software that uses the model has the potential to mitigate some of the big issues we face with machine learning today [325–327].

6.3 Design

The purpose of the Cirkus application is to playfully collect movement data from children with SBMD during circus courses to train machine learning models that can be used in future iterations of this technology. Cirkus is an app that supports many types of games where children move like animals such as kangaroos, lizards, frogs, crabs, bears, bunnies, and monkeys. The flexible app allows children to create their own games and rules as long as they move like animals. The app records movement (accelerometer, rotation, and bearing) data when children are performing as animals. The device is worn on the wrist while the app is running.

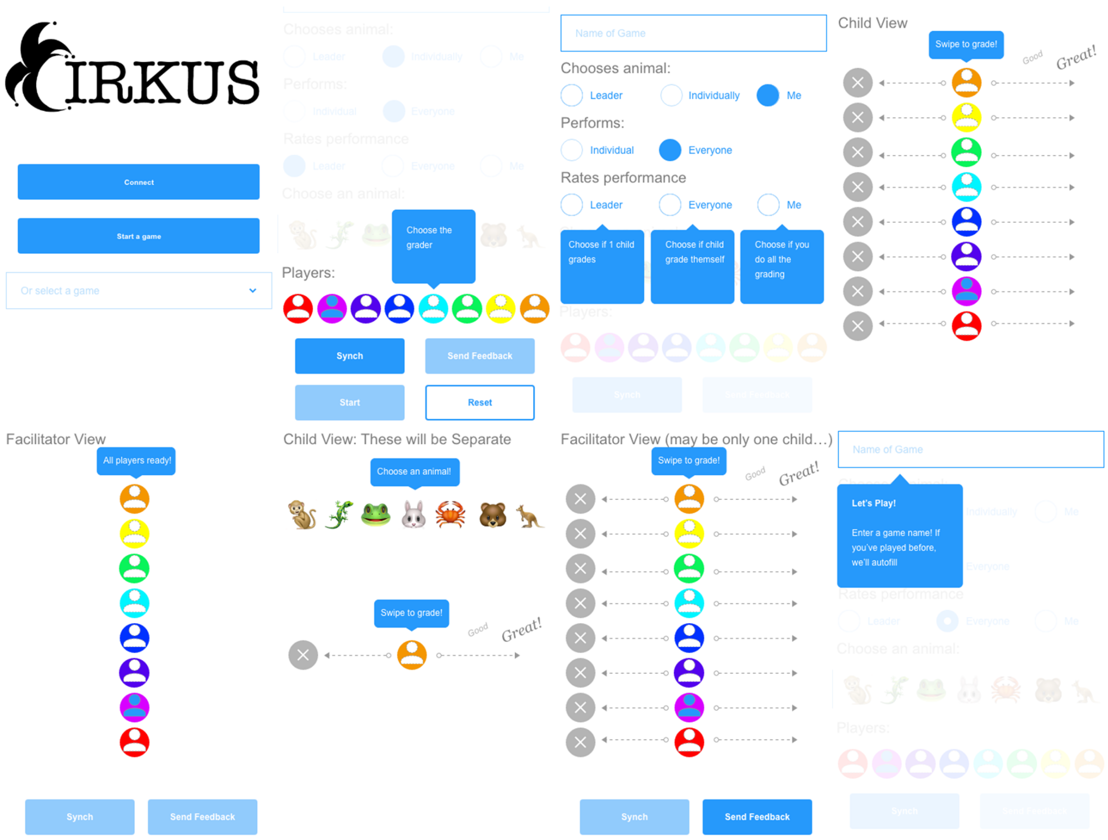


FIGURE 6.1: Screenshots of Cirkus Wireframe developed in Adobe XD

In this section, I describe the design process that informed the creation of Cirkus, followed by technical implementation details.

6.3.1 Inspiration and Pilot Work

In our previous work, warm-up games were an integral component to circus training workshops [26] because they prepared participants physically, socially, and mentally [234]. In these workshops, animal locomotion activities engaged and challenged children to work on their balance, strength, stamina, and movement planning in numerous warm-up games. For example, *Animal Tag* [234] was a warm-up game during which children moved like various animals while playing tag, but with variations such as asynchronous rules for the chaser and tagger or types of animals embodied. These particular warm-up games served as inspiration to develop the Cirkus app to support animal locomotion-themed games.

Figure 6.2: Images of children licensed from Adobe Stock for personas

Prior to development, I wanted to explore creating a generalizable play structure that affords nearly any animal locomotion game. To this end, I conducted a bodystorming [328] session using personas based on children from workshops in Sweden with high school interns participating in the Summer Internship Program[1]. Prior to the bodystorming session, I developed a series of incomplete personas that the high school students would complete and role-play during the session, shown in Figure 6.3. The pre-filled portion of the personas related to lived experiences of having SBMD—most were directly inspired by actual children with SBMD we worked with in prior research sessions. For example, the persona would describe how the child would act after struggling with a physical activity. High school interns completed the persona by stapling a chosen printed image licensed by Adobe Stock to the persona and filling in the missing portions, shown in Figure 6.4. The missing portions included elements beyond SBMD, but relevant

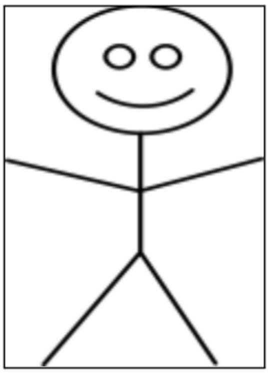
[1] https://sip.ucsc.edu

My name is:

My age (between 9 and 11) is:

At home, I live with (who? Siblings, parents, tutors):

I love:
- Fantasy
- Narrative
- Role playing
- Exploration



Superpowers:

	When it comes to physical activity, I: • Am very enthusiastic with new activities • Love to try new things • Love the idea of circus training

Challenges:

• I get tired and bored easily • It's hard to keep doing an activity for long • I am easily frustrated	When it comes to physical activity: • I fumble and fall a lot • I find it hard to complete sets of movement • It's hard for me to plan my next movement • I find very difficult to copy movements

Activities I like are:

	In Circus training, I've liked: • Free play with balancing board • Warm-up games

Activities I dislike are:

	In Circus training, I'm not a fan of: • Aerial acrobatics because it is quite hard • Juggling with balls and clubs

When struggling with a physical activity:
I tend to quit when exercises are hard. I also find creative ways to cheat, and if I get caught, I make up stories to cover it up.I'm also great at finding better things to do instead.

Figure 6.3: Partially filled in persona for bodystorming session

to designing circus-themed animal movement-based games, including motivations, game interests (e.g., fantasy, exploration, narrative-based), names, and age. Prior to the session, high school students were briefed on the goals and instructed to be respectful when role-playing because the personas are, in part, based on real individuals with a disability. This session was not intended to be an empathy-building experience for the high school students but rather an exercise of grounding the design context with intention. The goal of this work was a generalized play structure that could support games this population could theoretically play, not the designs themselves. It was more important to ideate many games than to consider designs that would directly inform the end product.

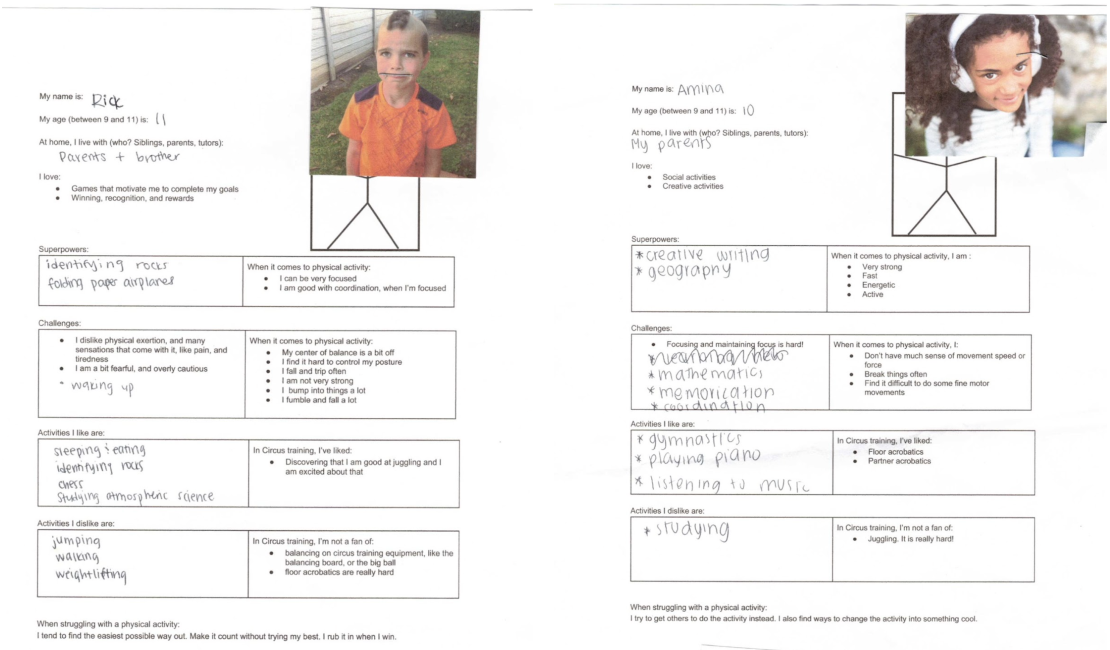


FIGURE 6.4: Personas completed by high school students participating in Summer Internship Program

Prior to the bodystorming activities in the session, we completed a warm-up. With music playing, we explored movement by partnering up and mimicking motion with alternating leads. During these motion activities, high school students were instructed to move in character for their persona. After warming up for approximately 15 minutes, we moved on to the design portion of the session, employing bodystorming methodology [329]. During bodystorming, we ideated movement-based games proposed by the high school students role-playing children with SBMD. Each high school student was responsible for leading the generation of one game idea. Once an initial idea was proposed, all of us acted out a complete play-through of the proposed game, iterating on rules and expanding on the idea as necessary to complete the full experience. After each game, we debriefed and added notes to a whiteboard before moving on to the next game. After approximately 1.5 additional hours, all high school students invented an idea that was role-played and bodystormed. Thereafter, high school students created paper prototypes or sketches that visually describe their idea to be included in the final presentation of the Science Internship Program. A subset of these are shown in Figure 6.5.

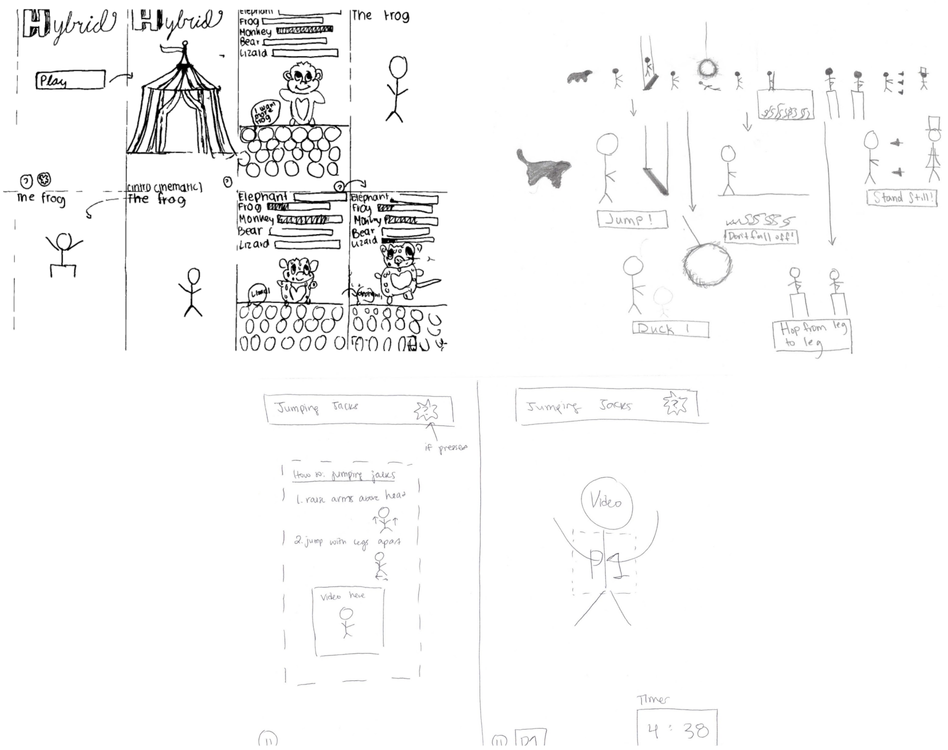


FIGURE 6.5: Sketches or paper prototypes of games ideated by high school students during bodystorming session

High school students created three games. The first, depicted in the top left of Figure 6.5, is a game where children move like various animals to create hybrid animals. The game gives goals such as "make a pure monkey" or "make a monkey/frog hybrid". Additionally, groups of children could move and collaborate to create interesting hybrids. The second game, shown in the top right of Figure 6.5, is an obstacle course game where children complete sequences of goals to get to a treasure and compete against each other for the best time. This game was inspired by *Temple Run*. The third game, shown in the bottom of Figure 6.5, was inspired by *Minute to Win It* where 2 teams of partners battle to get the most points by completing movement-based goals prompted by the device. For example, players may be prompted to do jumping jacks as a lizard.

I created a design document that included movement games described above as well as games previously played with our target population during previous research. *Statues* is a game where children need to move from point A to point B moving like a prescribed animal each step of the way. If players do not freeze their movement when the facilitator turns around, they are eliminated. *Swallowing Tide* is a game similar to statues, but instead of trying to reach a destination, they are running from a wave that progressively moves faster. *Freeze Tag* is a game where children move like an animal and are frozen by the facilitator or elected leader when their movements are deemed lacking. *Simon Says* is a classic game where commands in the form of animal movements are shouted out but should only be performed when preceded by the phrase “Simon says...”. *Animal Trophies* is an activity that awards animal performances based on criteria such as most expressive, most effort, or slowest lizard. *Animal Charades* is a game where audience members have to correctly guess the performer’s animal. *Hot Potato* is a variation of Animal Charades where the performing role is passed along a circle until a song is stopped and the current performer is then eliminated. *Animal Tag* is a game where a leader or facilitator calls out animals and everyone is allowed to make one step as that animal while the player who is “It” tries to tag other players who also become “It.” *Ninja Rock, Paper, Scissors* is a game where pairs of children rotate in a circle choosing to perform one of three animals competing to be the last player standing. The three animals have relationships where animal A beats animal B, animal B beats animal C, and animal C beats animal A. *Food Chain* is a variation of *Ninja Rock, Paper, Scissors* where all players choose to perform an animal at the same time and a facilitator or leader calls out the "predator" of the round, which eliminates everyone who performed like that animal's "prey." The final game in the design document is *Animal Spirit Grid* where children progress on a floor grid of "bombs" and "animal spirits" to find the sequence of safe squares and animal movements to make it to the other side of the grid. Using this design document, I worked on a simplified structure that would support each of these games by inductively iterating on a general play framework. This play framework became the basis for our interface design, described below in Section 6.3.2.

6.3.2 Flexible Play Structure

The inductive analysis of the games in my design document resulted in an abstracted set of discrete settings that can be used to describe each of the games in whole or by sequencing this generalized play structure. The first setting is who chooses the animal to be performed. The options are the facilitator, a child leader, or each individual child chooses for themselves. The second setting is who performs an animal movement. The options are either one individual performs or everyone performs. The final setting for every round is who rates the performance. The options are a child leader elected by the facilitator rates the performer or performers, everyone rates themselves, or the facilitator rates everyone performing. A fourth option, "None", was added later to remove the rating features entirely for cases that rating and seeing ones performance may cause anxiety or when fast-paced rounds are needed. Based on the above selections, contextual options appear. If the facilitator is choosing the animal, they can select it immediately. If a child leader needs to be elected to either choose everyone's animal or rate the the player(s) who performed, those roles are selected by tapping on the player icons. With this information, all sequencing of events to support all of the games in the design catalog are accounted for. I created a wireframe of Cirkus in Adobe XD, shown in Figure 6.1, to test each game in the design document to ensure this generalized play structure could support each of the games. For example, in *Food Chain*, described above, the app would be set to everyone for choosing the animal (each child chooses one of three animals to perform so the app knows which data it is collecting—the "predator" is irrelevant to the app's function), everyone is selected for who performs, and the rater would be the facilitator, who eliminates the "prey." These rounds would continue until one player remains or all players are defeated. In *Animal Spirit Grid*, if a child wanted to guess an animal spirit on a square that is not a bomb, the settings would be everyone for who chooses the animal (everyone in this case is the singular child), individual for who performs, and facilitator for who rates because they have the secret key. Based on these selections, the app intelligently decides supplemental screens for players who can choose to interact—in this case, even though the final rating is decided by the facilitator, the audience and individual performer can enter ratings as well to judge how well the animal movements were performed (regardless of whether the animal choice was right) which is useful for training the machine learning algorithm. Figures 6.6-6.8 depict the implemented user interface for the facilitator (single iPad user) and Figures 6.9-6.13 depict the implemented user interface for the players (multiple users using iPhones or iPods).

6.3.3 Technical Implementation

Cirkus was developed in Apple's Xcode and written in the Swift 5 programming language. The app uses both UIKit and Spritekit, which are frameworks that provide infrastructure for building iOS apps. HealthKit is the framework I employed to access the motion data while the app recorded animal movements. The

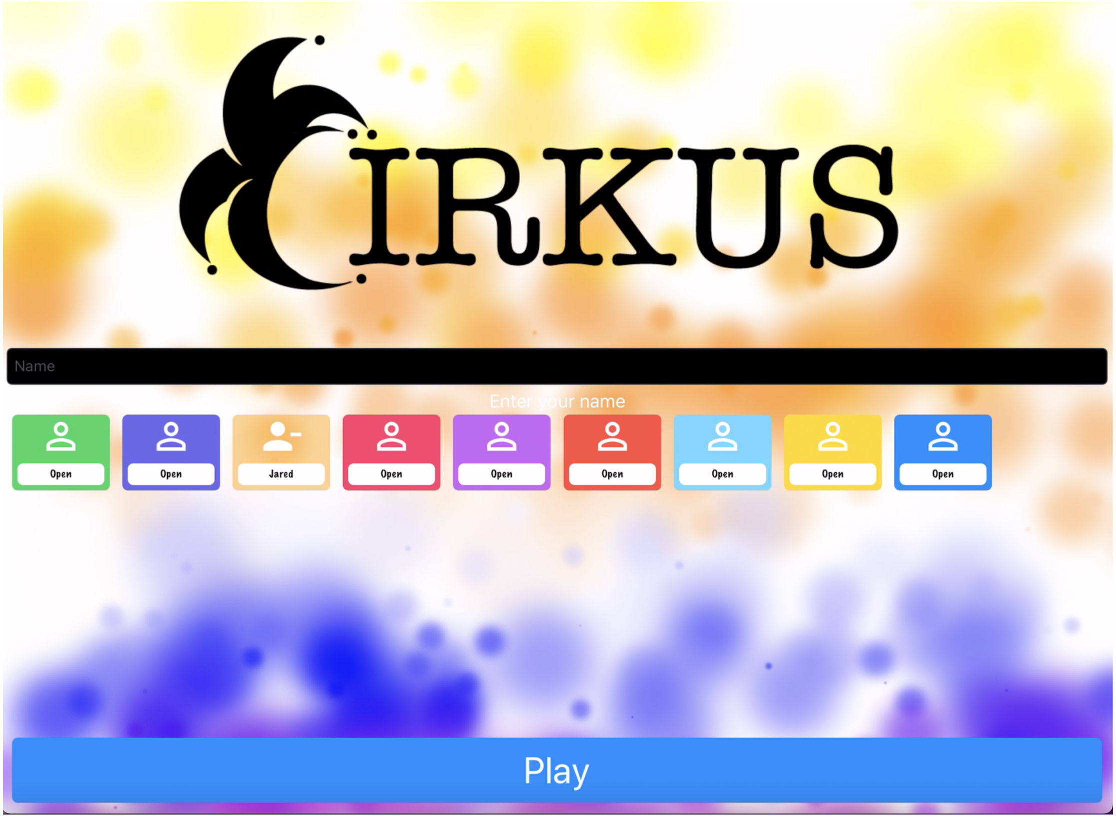


FIGURE 6.6: The facilitator's view of the matchmaking screen. The facilitator can remove players if they spell their names incorrectly or are eliminated from a previous round in a game

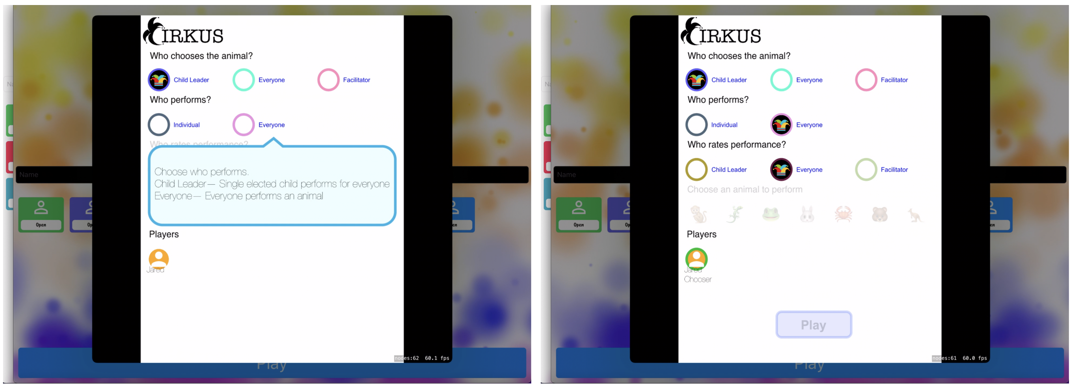


FIGURE 6.7: Screenshots of the facilitator's user interface for setting up a game round, which includes a contextual helper bubble that moves with the selections and contains helpful text for deciding between the options

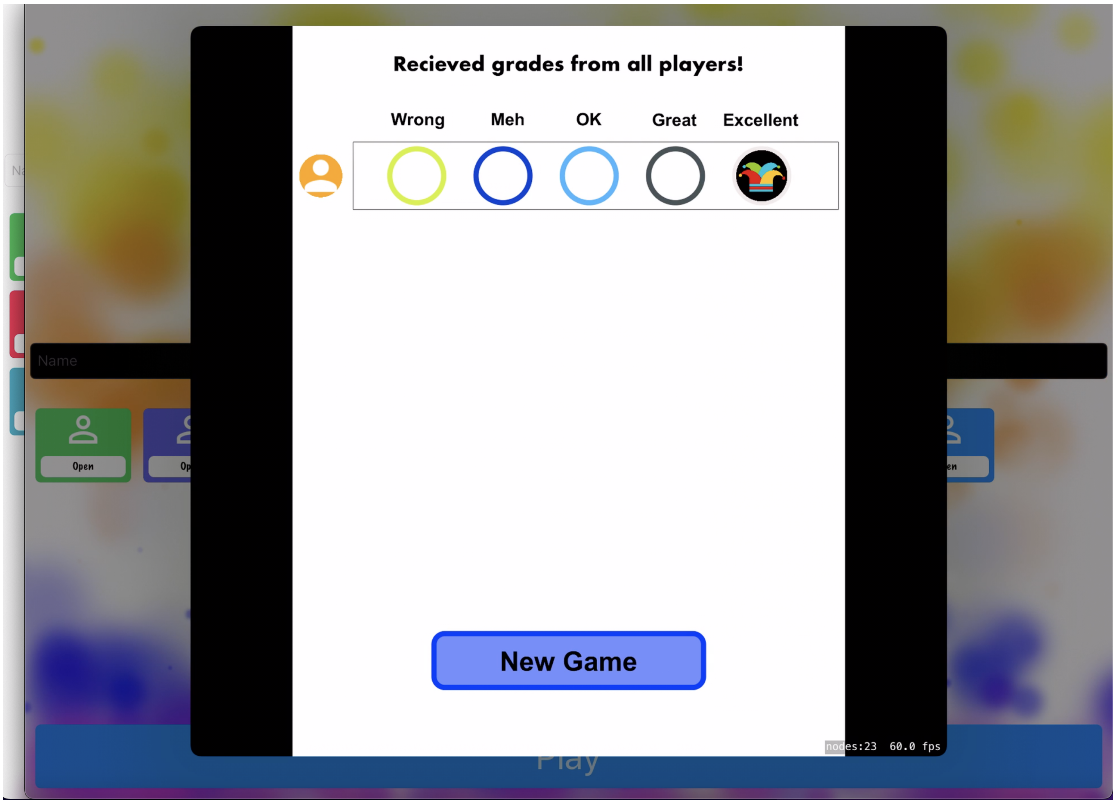


FIGURE 6.8: Screenshot of the user interface the facilitator uses to rate each player (rows are added to the table when there is more than 1 performer). The facilitator can immediately initiate a new round with the same settings or choose to go to the round settings interface to update the app for the next round of play

networking of the application was developed using Google Firebase's Firestore Database product.

Within Firestore, are 2 collections that provide the functionality needed to run Cirkus, shown in Figure 6.14. The CirkusRound collection contains a single document with 13 fields. Most of the fields correspond to the options chosen by the facilitator described in Section 6.3.2. Additionally, are the logistical fields necessary for the function of the app including the names of the players (fruits in the screenshot for anonymity), the gameState which keeps track of the progression of a game round (waiting for a match, waiting for the match to start, creating a game round, choosing an animal, performing the animal, rating the performance, and receiving feedback), a 2-dimensional array of grades for all the players from themselves, to each other, and from the facilitator, and a timestamp. Each client listens

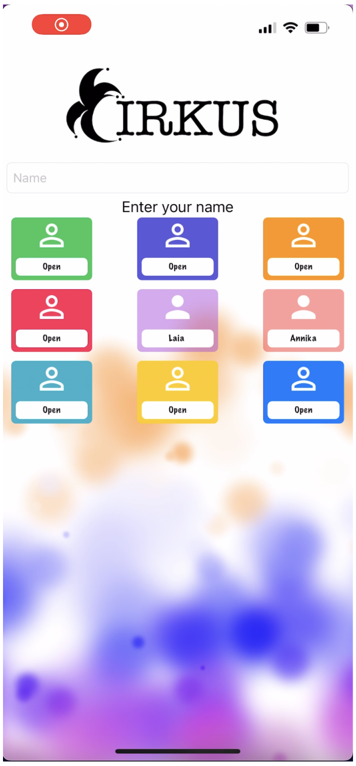


FIGURE 6.9: Screenshots of the players' user interface for joining a game round, which is where they select their color and enter their name

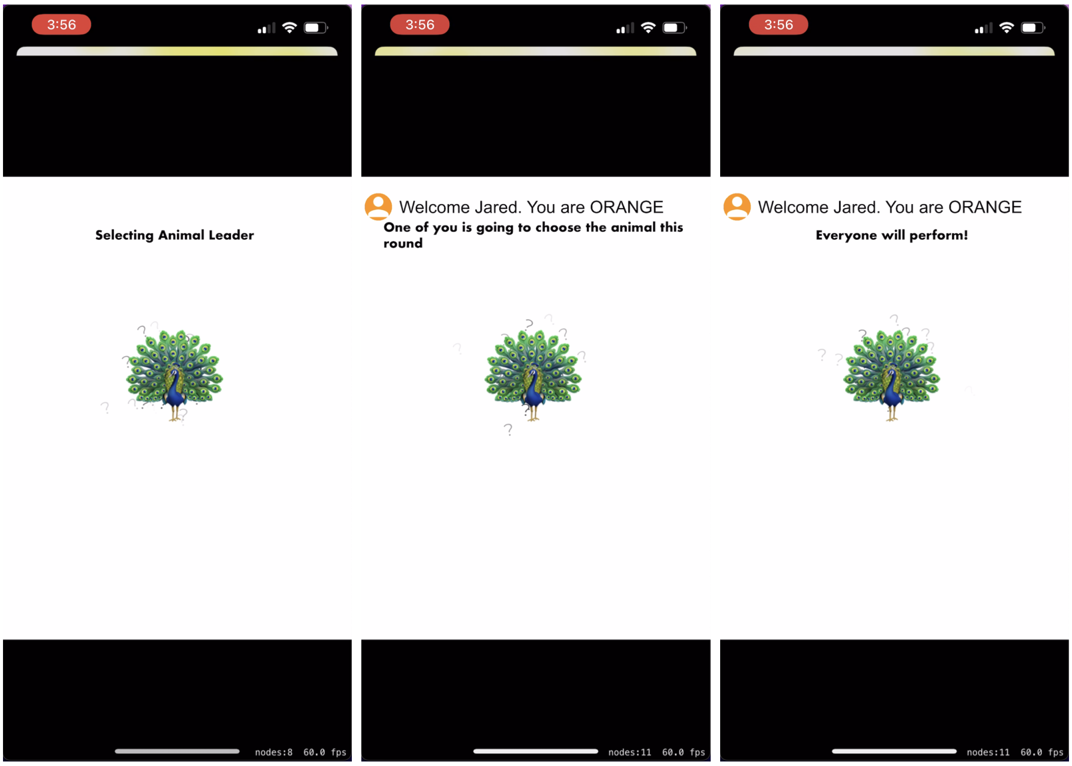


FIGURE 6.10: Screenshots of the players' user interface that provides real-time updates based on selections made by the facilitator

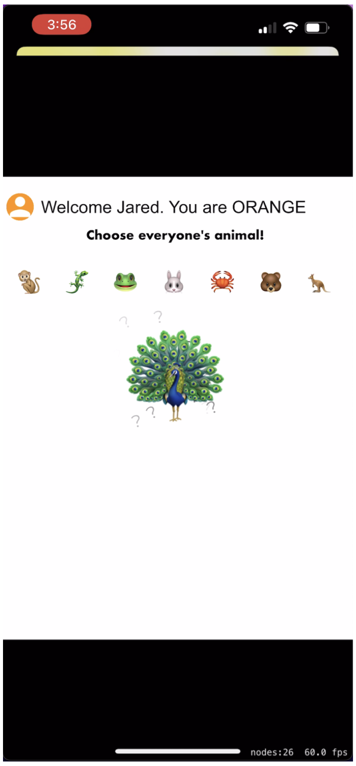


FIGURE 6.11: Screenshots of the players' user interface that provides players the option to choose an animal for themselves or everyone depending on the selections previously made by the facilitator

FIGURE 6.12: Screenshots of the players' user interface that provides a player haptic feedback and visuals so they know the animal they should perform as well as how long to perform for (as long as the haptic feedback continues)

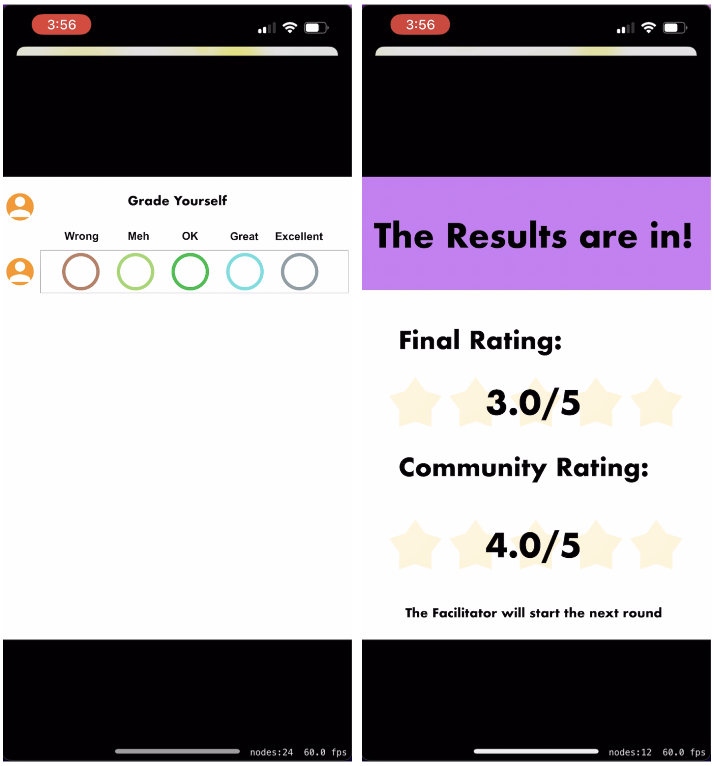


FIGURE 6.13: Screenshots of the players' user interface that provides players the option to rate their own performance or the performance of other(s) depending on the selections previously made by the facilitator as well as the results screen

for changes to these fields and responds accordingly. Updating the gameState progresses all clients to the corresponding screen. Each new game round overwrites the active document. The second collection, MotionData, contains a document from every player after every game round.

When the facilitator starts a game round and moves to the performing state, each player's device begins recording motion data at 120hz. This motion data includes motion data on all three axes, rotation on all three axes, a heading, and a timestamp. This data continues to be recorded until the facilitator progresses the app to the rating state. After everyone rates their performance and the facilitator sends the signal to move to the feedback state, each client asynchronously posts their document to the MotionData collection which includes an array of each snapshot of data at 120hz as well as a copy of the CirkusRound data to provide context to the motion data. The combination of motion data from each device and

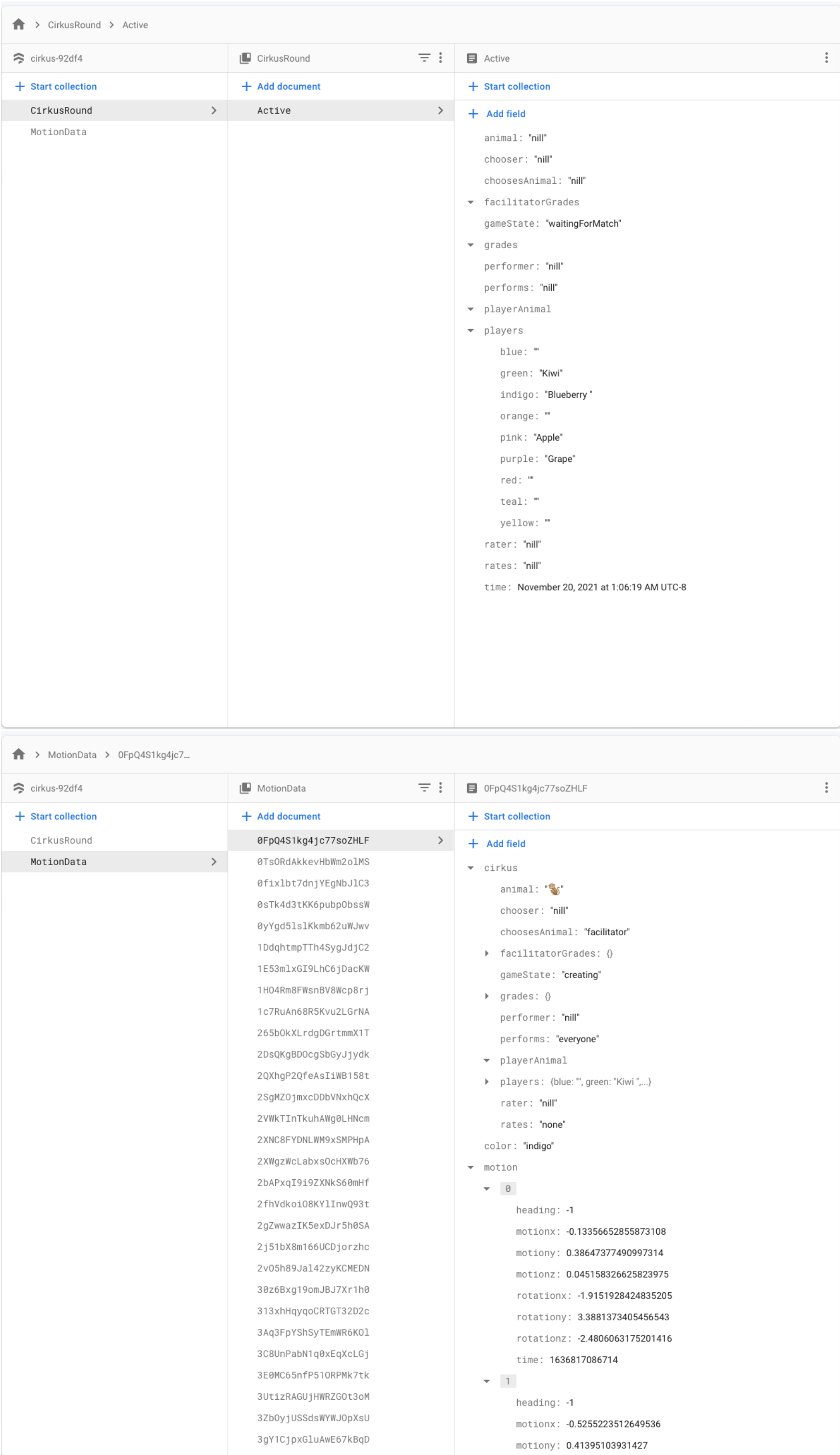


FIGURE 6.14: Screenshots of the Firestore database that serves as Cirkus's back-end infrastructure

copies of the CirkusRound data can be used to train machine learning models.

The networked data is coded and encoded for small transfer sizes and low latency. Within the application, all data except for names are represented as Enums, but stored as an 8-bit integer. Local application logic uses all of the CirkusRound data to intelligently update the users with important information. With knowledge about the number of players, the type of round (i.e., everyone chooses their own animal, everyone performs, everyone rates themselves), and the game state, the app can display contextual updates. For example, the facilitator can keep track of the number of ratings received in the rating state as well as which are missing so that the facilitator can organically help players in situ and prompt them.

6.4 Workshops

To test the implementation of Cirkus, collect movement data from our target population, and co-create games supported by Cirkus, we ran a series of workshops in Sweden in collaboration with Uppsala University and the largest circus company in the country, Cirkus Cirkör. The following research questions drove our work

RQ1: *What games do children and circus professionals co-create using the Cirkus design probe?*

RQ2: *What are the implications for using a design probe to collect machine learning motion data from children?*

RQ3: *How might these models be used in future designs?*

Each workshop was recorded from multiple angles using GoPro cameras and tripods. One GoPro was held by a research assistant to catch closeups of interesting interactions. The high definition footage was later compiled into a single

	Workshop	Sex	SBMD
P1	Control Circus	M	-
P2		F	-
P3		F	-
P4		F	-
P5		F	-
P6		F	-
P7		F	-
P8		M	-
P9		F	-
P10		F	-
P11		F	-
P12	SBMD Sensitation	M	✓
P13		M	✓
P14		M	✓
P15		M	✓
P16		F	✓
P17	School	F	-
P18		F	-
P19		F	-
P20		M	-
P21		F	-
P22		F	-
P23		F	-
P24	Lab	F	-
P25		M	-
P26		F	-
P27		M	-
P28		F	-
P29		M	-
P12	SBMD Co-Creation	M	✓
P13		M	✓
P14		M	✓
P30		F	✓
		13M - 17F	**6 SBMD**

TABLE 6.1: Breakdown of participants from each workshop. Participants with SBMD may be under-reported. There was some participant overlap between the second and fifth workshop.

4k video with all the camera angles synchronized by audio in Adobe Premiere. Additionally, the GoPros were used to make audio recordings of researcher debriefing sessions at the conclusion of each workshop. Cirkus records movement data as well as timestamps so that telemetry could later be compared to the video footage for additional context on the quality of the movement.

This research was approved by the Swedish ethics board. All parents and children signed consent forms detailing the research protocol and data collection. No identifiable information was stored by Cirkus (no names were real participant names and the motion data could not reasonably be used for gait identification). All data stored by the app and video footage are stored in Sweden to adhere to GDPR regulations. No images that include faces of workshop participants are included to preserve anonymity.

6.4.1 Control Circus Workshop

The purpose of the control circus workshop was to pilot the technology and collect movement data from children without SBMD who could be used as a control for comparison and machine learning. Participants in this workshop were not recruited based on their SBMD status and many did not have any disabilities. It is possible that children who participated by chance had SBMD because we did not ask. In this workshop, Cirkus was used as a warm-up activity. One of the circus trainers led the activity by explaining and demonstrating the motion of an animal. Then, the children traversed the room as the animal all at once. While children moved, circus trainers gave feedback and encouragement. The process repeated until all of the animals in the app were explained, demonstrated, and performed by the children. I took the role of the facilitator using the iPad. The settings were: facilitator chooses animal, everyone performs, and facilitator rates (I skipped rating to keep the pace fast and after this workshop, I introduced the no rating option to streamline the app for situations where rating would impede the activity).

In this workshop, the app took a passive data collecting role and children only referenced it to know when to begin moving. This workshop was a useful sensitizing experience for the circus trainers as well to become more familiar with the app—it mitigated concerns of the technology being overly distracting. Considering this was the first real test of the app, it worked well even under conditions that were not ideal. There was a WiFi outage in the building, so we used my iPhone's hotspot and connected all nine devices to it. The mobile signal strength was medium, but I was further concerned with how well my hotspot would perform in an international setting on an American phone plan. However, all of the devices were responsive (transitioning within 1 second of one another) and successfully uploaded the data they collected. There were no cases of total technology breakdowns and small blips were automatically corrected using a dismissive swiping gesture on the facilitator iPad that resets all the devices connected to a session to the beginning of a new game round—which seemed to go unnoticed by everyone. This "remote reset" feature was not needed very often, but built trust in the technology because we did not need lengthy interruptions in the activities to deal with the technology. Another safeguard that helped the workshop run smoothly was placing all of the technology in Guided Access mode, also known as kiosk mode, which disables all of the physical buttons, keeps the display on, prevents locking the device, and forces the Cirkus app to remain in the foreground. Ensuring the device was awake and running Cirkus for the entire workshop helped reduce the chance that network interruptions could take place.

After the warm-up activity using Cirkus, children participated in circus training activities outside of this research and therefore, the technology was returned to me. After the children left, we met with the circus trainers to answer any questions they had about the technology and plan for the sensitization workshop for children with

SBMD, described next in Section 6.4.2. Between the workshops, I made usability improvements, such as adding the no rating feature and a new button for the facilitator to quickly start a new round with the same players and same settings. I also made a pass at the movement data the app collected to ensure all of the data was present and that it passed a sanity check. The video footage was stored to an external hard drive and the GoPros were erased for the next workshop.

6.4.2 Sensitization Circus Workshop

The purpose of the sensitization workshop was to non-intrusively introduce the tech to our target population of children with SBMD. At the beginning of the workshop, children arranged themselves in a circle and played a warm-up game where they would hear their name, catch a ball, call out a name not previously said, and pass the ball to that person. The ball eventually made it to everyone and ended back at the first person, who restarted the process. Eventually, additional balls were added and the circle became random wandering. Next, children practiced dribbling—we embedded standardized physical assessments throughout multiple activities to make them more naturalistic. Dribbling yielded to synchronized catch where pairs of children would simultaneously throw the foam ball to each other and try to catch the incoming throw. The remaining activities for the standardized test (not used in this research, but within the larger project) were incorporated into an obstacle course that ended with a celebration of cheers, high-fives, and flashlights waving. The obstacle course started with jumping into rings laid on the ground. Then, children did an exercise similar to running in place, except each step had a pause in between and their hand opposite the foot in the front would be swung above their head. Many children had trouble coordinating this movement, which is a symptom of SBMD. One child playfully turned to dancing after struggling. Next, children hopped across the room on one leg and walked back like a penguin, keeping their knees together. After this, they jumped over a foam block and across a longer distance indicated by tape on the ground. The final obstacle was stepping though a hula hoop held a few inches off of the ground by a circus trainer.

After the obstacle course, children were outfitted with the Cirkus app. Similar to the process described in Section 6.4.1, a circus trainer went through the animal movements one-by-one and had the children practice them. An interesting outcome of this activity was that one of the children who had disengaged earlier was able to rejoin activities through controlling the iPad, assuming the role of the facilitator. Controlling other devices prompted more in-depth questions that I answered about how the app collects data and the purpose of the data. My collaborators had more objectives for this workshop, so there was not time to play games using Cirkus after learning the animal exercises. The children then paired up and used laser pointers in an activity where one child would shine the light on the hands or feet of their partner and the two would collaborate while the child with the laser guides their partner through movements, trying to keep the pointer on the same spot. The workshop ended with an exit survey for the larger research project. The movement data collected from the first and second workshops was collected in the same manner and intended to be used for comparison in the machine learning training. As described further in Section 6.5.2, the accuracy of the model was equally worse when either set of data was removed—the training improves with more data and there is limited data to begin with.

6.4.3 School Workshop

The purpose of the school workshop was to understand how Cirkus performs in different settings and to pilot my co-creation protocol. Additionally, the games designed and played in this session were able to be iterated on and evaluated by children with SBMD in the final workshop, described in Section 6.4.5. This workshop took place at a local school within walking distance from Uppsala University. I brought 4 GoPro cameras, tripods, and ribbons that matched the colors in the app. Prior to the session, parents signed consent forms. The session was scheduled immediately after school for roughly an hour and a half. We did not ask about disability status for this workshop because it was meant to pilot our co-creation protocol. Therefore, it is possible that participants had a sensory integration disorder, but we did not observe any symptoms from any of the children in this group. A colleague from the lab I was visiting joined me to help translate and a teacher for the school was present to help as well. Many children understood English, but were not comfortable speaking in English, so the whole session was translated to Swedish by my colleague.

After briefing children on the goals of the session while sitting in a circle, we began by asking children how each animal should be represented and interpreted by the technology. In prior sessions, circus trainers taught the children rigorous movements that were physically challenging. Outside of the circus environment, we were interested in democratically allowing children to decide how they would like to be represented in the technology. We believed this could potentially offer interesting insights into the differences between choreography created by circus professionals for children with SBMD and by children generally. We highlighted that three of the animals hop (frog, rabbit, and kangaroo), so we prompted children to think through how the technology could distinguish the different animals using probing questions such as “How will the Cirkus app know the difference between a frog and rabbit movement.” Children decided on variations such as the height of jumps, the distance of the jumps, the frequency of the jumps, the depth of the jumps (how low of a squat entered on return), and arm positions. For example, a frog jump requires a full squat and the hands are placed on the ground in between each large hop, while a bunny hop comprised tucked arms with frequent small hops, while keeping the knees together. The kangaroo was upright with tucked arms, similar to the bunny, but had much larger and less frequent hops. This same process was used to distinguish between the crawling animals, including the lizard, bear, monkey, and crab. The lizard was a crawl where the stomach was as close to the ground as possible, the monkey moved much like the frog except one leg hopped at a time and the arms swung in 90-degree angles, the bear required the arms to move together and the legs to move together, and the crab was a belly-up crawl.

The first game children played was *Animal Crossing* where if the facilitator guessed each child's movement correctly, they stayed, otherwise they had to take a step back. The goal was to be the first to arrive at the other side of the room. In the first round of this game, I had a difficult time keeping track of all of the children's movements, so I divided the children into three groups and asked my colleague and the teacher to help me by sharing in the role of facilitator. Many children cheated by choosing animals that they could traverse the room quickly with, so we played a variation of *Animal Crossing* called *Animal Tournament* which has the same mechanics, but after each round, the start line is moved up by a third of the space so that after three rounds, the children in the lead are all winners. We created this variation to accommodate the smaller space the classroom afforded and to mitigate cheating.

After playing *Animal Crossing* and its resulting variation, we moved on to the co-creation portion of the workshop. I reminded children that the one rule was the games they proposed required moving like an animal. The first idea proposed was *Labyrinth*. One child proposed the idea "A labyrinth where you go as an animal and specific parts of the labyrinth you go as specific animals" I responded "I love that! I have just the thing." and I proceeded to take out the ribbons and asked children to mark off 4 "rooms" of the labyrinth on the floor where the color of ribbon corresponded to different animals (green for frog, brown for monkey, pink for bunny, red for crab). After children split up to the rooms and performed as the animal, I said that the animals were still trapped and that perhaps if the children tried a different combination, that they would be able to escape. Following the reshuffling, I went to the doorknob and dramatically tried to open the "locked" door but it would not budge so we repeated the process. I was thinking on my feet to generate a win condition. To this end, I told the children in the frog room that they had the correct number of animals, so they should shuffle the other rooms to figure out the winning combination. Children were so excited when I dramatically opened the door and they celebrated their victory with applause and dancing.

After playing *Labyrinth*, a different child ideated a game where animals had to find secret objects around the room. I proposed that these objects could represent food. I suggested we include animals in this game that were not included in the last game, which meant children had to search for lizard food, kangaroo food, and bear food. Each of the three facilitators was in charge of a particular animal and knew where the food was hiding. The facilitators made animal sounds that grew in frequency and loudness as a child got closer to the food source object. In this iteration of the game, called *Hunter Gatherer*, the animal noises and the objects representing food were a source of humorous play. For example, the lizard sound was a prolonged /s/ sound which was hard to make louder and the kangaroo food was a dinosaur model. Before ending the workshop, we ran a debrief circle session with the children on how well they enjoyed the games they created, the Cirkus app, and feedback on the session.

6.4.4 Lab Workshop

The structure and motivations of the lab workshop was similar to the school workshop. In addition to co-creating new games with children, I was interested in having the children test out and evaluate the games created by the children from the school workshop. The lab workshop was conducted in a research space at Uppsala university and many of the participants were children of the faculty. In this workshop, two parents stayed to observe and one grandparent, who is famous in the HCI field, generously volunteered to translate because the lab director was ill and unable to attend. Like the previous workshop, the lab workshop lasted approximately one and a half hours, and we began with a briefing session followed by choreographing of all the animal movements. The first game we played in this session was *Labyrinth* and I came prepared with the solution to the animal combinations on a piece of paper. In this play test, all seven types of animals had a designated room, causing the difficulty and length of the game to be increased. Much like the first session, the children danced, giggled, and clapped when the door finally opened.

Next, we began the co-creation portion of the workshop. First, we answered many questions about who came up with the previous games and who would play the games they create. The first game the children created was a combination of multiple ideas—one idea was a point system that started at zero and went up or down depending on animal movement performances, and the second idea was about partnering up to guess another player's animal performance. Together, these ideas resulted in *Guess* where pairs of children would take turns performing animals and guessing to increase their score. The next game children created was called *Popcorn* where children would occupy animal areas similar to labyrinth but instead of changing combinations, they would pass a ball between the rooms which signaled the active room that needed to perform. Similar to the previous sessions, we ended the workshop doing a circle debrief.

6.4.5 SBMD Co-Creation Circus Workshop

The final workshop took place at Cirkus Cirkör with many of the same children from the sensitization workshop—two children did not return and there was one new participant with SBMD.The purpose of the workshop was to co-create games with children with SBMD who have been exposed to the tech in the first workshop (excluding the new participant). Additionally, this workshop allowed us to test some of the games in the catalog with our target population. Like the first workshop, there were research objectives beyond the scope of Cirkus. The session began with children circling up and warming up by assuming a push-up position (knees on the ground was encouraged for those struggling) and alternating from open hands to fists on the ground. The first game children played using Cirkus was *Hunter Gatherer*. The environment was much larger than the classroom and initial adherence to moving like the animal yielded to regular walking within a couple of minutes for all but one determined child (the girl). Once the quality of the movements in most children dropped, I stopped the recording within the app, but the game continued.

After regrouping, the circus trainers proposed a new game based on ideas the children had. The child who had a breakdown in the sensitization workshop and was reintegrated into the activities through taking the role of the facilitator was excited by Cirkus in this workshop and participated with the wearable. All the players began by laying on the ground, face up, waiting for the countdown to wake up. Once awake, the players moved like animals to find higher ground to escape the lava. No two players could use the same platform. In the second iteration of this game, once they found shelter on higher ground, the Cirkus app prompted them with a random animal that they had to metamorphose into and whose moves they had to mimic. I named this game *Rise!*. Next, children took a break from Cirkus and practiced their acrobatics by hanging upside-down from a suspended bar. Next, children played a game similar to Twister but using colored plastic loops on the ground rather than a mat. Finally, children filled in a survey for the broader research project. At the end of the workshop, all of the children expressed interest in using the app again and asked me to leave the devices in Sweden so they could play again, which I did.

6.5 Results

In this section, I share the resulting games of this research, including the games that inspired Cirkus from previous workshops and those that were co-created within the five workshops presented above. Additionally, I share the resulting machine learning work that was enabled by the movement data collected by the Cirkus application.

6.5.1 Catalog of games

Who:	**Chooses Animal**			**Performs**		**Rates**			
Game	**Leader**	**Everyone**	**Facilitator**	**Individual**	**Everyone**	**Leader**	**Everyone**	**Facilitator**	**None**
Statues			✓		✓				✓
Swallowing Tide			✓		✓			✓	
Freeze Tag	✓	✓			✓	✓		✓	
Simon Says	✓		✓		✓			✓	✓
Animal Trophies	✓	✓	✓	✓	✓			✓	
Animal Charades		✓		✓		✓	✓	✓	✓
Hot Potato		✓	✓	✓			✓	✓	✓
Animal Tag		✓	✓		✓			✓	✓
Ninja Rock Paper Scissors		✓	✓	✓			✓	✓	✓
Food Chain		✓			✓			✓	✓
Animal Spirit Grid		✓		✓				✓	
Animal Crossing		✓			✓	✓		✓	✓
Labyrinth		✓			✓			✓	
Hunter Gatherer		✓			✓			✓	✓
Guess		✓			✓		✓		
Popcorn		✓		✓	✓	✓	✓	✓	✓
Rise!			✓		✓				✓

TABLE 6.2: Table of all games, including games from previous workshops and co-created games. The potential settings within Cirkus for each game make up the rows.

Table 6.5.1 contains all of the games that inspired the creation of Cirkus as well as the co-created games resulting from the five workshops. All of the games can be supported using the Cirkus app. Descriptions of how each game is played can be found within the text of this chapter, above. Many games have multiple configurations that would work within the application, based on the desired play speed and the natural variations that could emerge. For example, many games could support either "everyone rates" or "no one rates"—a deciding factor might be if rating one's self would be disruptive to a fast-paced activity. Some games that require the facilitator to choose an animal could easily be changed into a game with an elected child leader. For example, in *Simon Says* either the facilitator or the child who won the previous game could play the Simon role.

One major observation that could fundamentally change the utility of the Cirkus app is teasing apart the two functions of the Rates category into separate categories. In its current form, the Rates category can be used to either assess the performance of an animal movement or broadcast the outcome of the game. For example, in *Simon Says*, a child could perform a kangaroo hop perfectly well, but still be eliminated because they moved without hearing "Simon Says." In cases such as these, it could be useful to rate the performance regardless of outcome to benefit the machine learning and reward the child for moving well. The Outcome category would house Eliminate, Positive, and Negative options. *Swallowing Tide* is a good example of when using the positive and negative outcome features could be useful because even if a child performs an animal well, they may still be swept up by the ever-increasing speed of the wave. Table 6.5.1 outlines how each game could be set up given this new possible feature.

6.5.2 Animal Movement Model

A major objective of this research was to use participatory methods to co-design games, while also collecting data for a more transparent and representative machine learning process. The team of researchers and I began this process fully

Who:	Chooses Animal			Performs		Rates				Outcomes		
Game	**Leader**	**Everyone**	**Facilitator**	**Individual**	**Everyone**	**Leader**	**Everyone**	**Facilitator**	**None**	**Eliminate**	**Positive**	**Negative**
Statues			✓		✓				✓	✓		
Swallowing Tide			✓		✓			✓		✓	✓	✓
Freeze Tag	✓	✓			✓	✓		✓				
Simon Says	✓		✓		✓			✓	✓	✓		
Animal Trophies	✓	✓	✓	✓	✓			✓			✓	
Animal Charades		✓		✓		✓	✓	✓	✓		✓	✓
Hot Potato		✓	✓	✓			✓	✓	✓	✓		
Animal Tag		✓	✓		✓			✓	✓			✓
Ninja Rock Paper Scissors		✓	✓	✓			✓	✓	✓	✓		
Food Chain		✓			✓			✓	✓	✓		
Animal Spirit Grid		✓		✓				✓				
Animal Crossing		✓			✓	✓		✓	✓		✓	✓
Labyrinth		✓			✓			✓			✓	✓
Hunter Gatherer		✓			✓			✓	✓			
Guess		✓			✓		✓				✓	✓
Popcorn		✓		✓	✓	✓	✓	✓	✓			
Rise!			✓		✓				✓			

TABLE 6.3: If a separate Outcome category were added to Cirkus, the resulting options for each of the games within this catalog are displayed in each row.

expecting an inaccurate model for multiple reasons, including messy data from the children, small amounts of data resulting from only five workshops, and differences in the choreography between groups. Therefore, we came up with preliminary ideas of how an inaccurate model could be useful, described in Section 6.6.1. The purpose of training a model was not to create a rigorous computational achievement that can diagnose children with SBMD—it was intended to be a source of play for this population. Therefore, the training of this model was conducted as a proof of concept that there exists a pipeline for training this type of model.

I tried multiple strategies to improve the quality of the model, including removing the first 180 frames of movement data from each entry to account for 1.5 seconds of reaction time and entering position, excluding various features (heading, rotation, movement), and excluding messy *Hunter Gatherer* data from the final workshop based on timestamps. These strategies resulted in four versions of the model, shown in Figure 6.15. None of the strategies resulted in significant improvement in model accuracy, likely due to the small amount of data available. Due to the negligible differences between these models, I did not try combining the strategies listed above (or combining subsets of these strategies), though with more data, that might be a useful approach for future training. I also gave the models varying numbers of training iterations to explore any correlations with accuracy, but after

100 iterations, the yields generally leveled out.

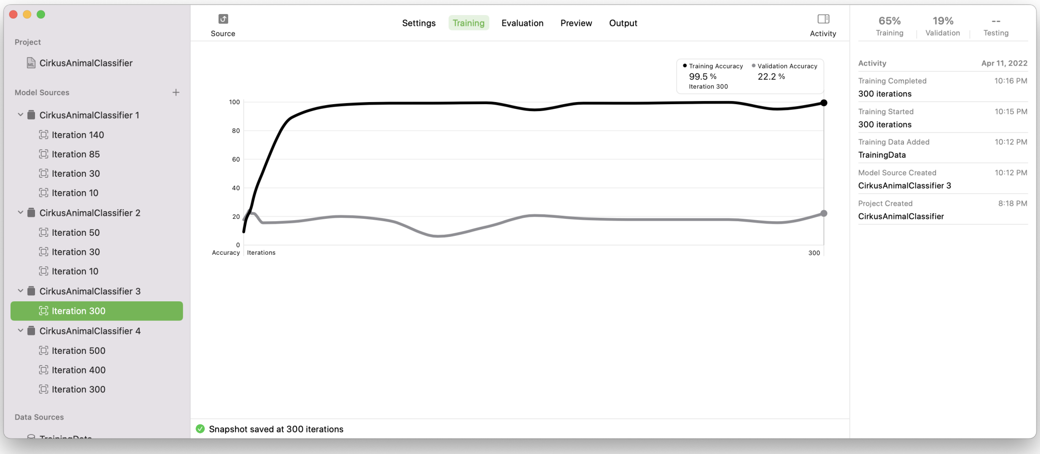


FIGURE 6.15: Screenshot that shows the training of the various approaches to training the machine learning animal classifier.

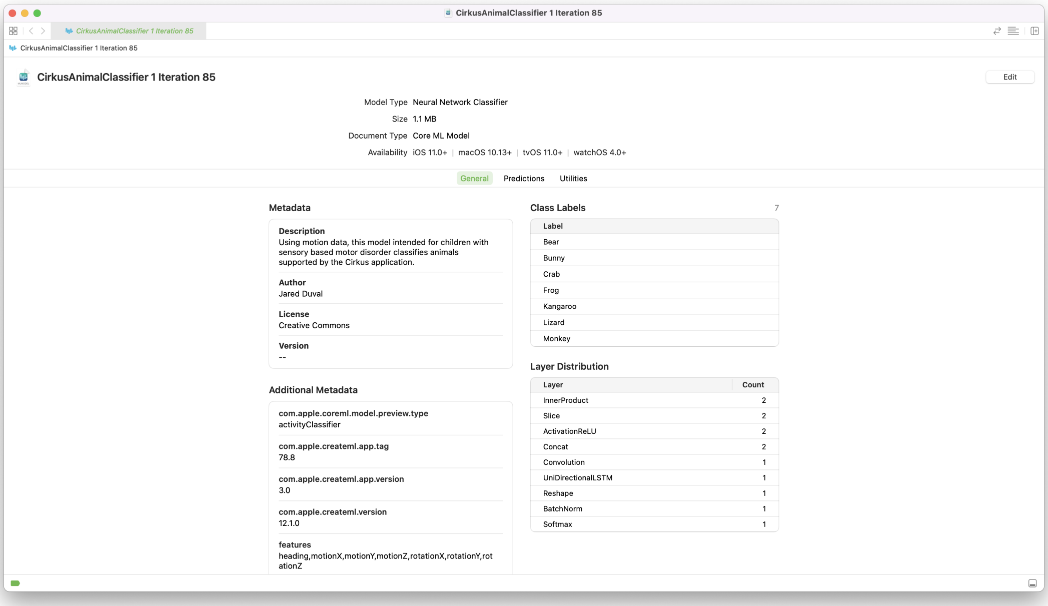


FIGURE 6.16: Screenshots of the resulting machine learning model that classifies animal movements

In the end, the first training session that had access to all of the data had the highest accuracy. The resulting model, shown in Figure 6.16, is a 1.1 Megabyte neural network. The small size of this model would be well-suited for running locally on a mobile device. The features of this model are heading and all three axis of motion and rotation, so this model would use all of the data made available by

Apple's CoreMotion framework. The layer distribution used for the deep learning are the defaults recommended by Apple for motion classification, but custom layers could potentially improve accuracy in future models trained on larger amounts of data. The outputs of this model include a Dictionary of label probabilities in the form of a (String : Double) where the Strings are the class labels and the Doubles are the prediction probabilities. The output also includes a String of the top prediction. An example output Dictionary could look like:

```
[
("Bear" : 5.6),
("Bunny" : 23.4),
("Crab" : 3.1),
("Frog" : 19.9),
("Kangaroo" : 28.5),
("Lizard" : 1.5),
("Monkey" : 18.0)
]
```

The probabilities will always add up to 100. In this example, the String output would be "Kangaroo" because that probability was highest. However, notice that all of the jumping animals have similar probabilities, meaning the model did not confidently distinguish between these movements. This would not be a surprise because I also often had difficulty distinguishing between the children's movements in situ. The overall accuracy of this model is 22.2%, which is about as accurate as a random guess. This accuracy was measured automatically by Apple's CreateML which intelligently separates the movement data into a training set (80%) and a validation set (20%). The (in)accuracy of this model met the expectations we set before the research began.

6.6 Reflection

The work presented in this chapter describes 17 games supported by the Cirkus wearable probe (RQ1). The flexible play structure of the app allows it to be used for a wide range of purposes, including as a warm-up tool, a game co-creation tool, an exercise tool, a source of motivation, and a data collection tool for machine learning. Cirkus worked in a variety of settings and contexts including in circus facilities with circus professionals, in a classroom with a teacher, and in a lab with researchers. The multiplicity of the app illustrates the value and benefits of a Serious Play for Health system.

Cirkus is neither a therapy-first approach nor a game-first approach—it explores a new domain (circus arts) for treatment of SBMD. While there is evidence that circus arts have shown promise for physical therapies, as discussed in Section 6.2.2, this research represents new possibilities rather than augmenting established medical practices. Therefore, Cirkus exists in the middle of the game-therapy-first spectrum. Additionally, the approach to machine learning is quite different than traditional health systems and the resulting potential integration of the models are novel (RQ2), as described next in Section 6.6.1.

6.6.1 Participatory Machine Learning with Children with SBMD

As described in Section 6.5.2, the model I trained is highly inaccurate, but that does not mean it is useless. While the model may have little utilitarian value, it has plenty of play potential—and this is what it was truly designed for. I intended for the model to be inaccurate because the model can then be incorporated into Cirkus's design as an antagonist. Pitting players against technology has the potential to be a source of great fun if carefully thought through. This model could be an added option in Cirkus's Who Rates category (RQ3). When the facilitator chooses ML in the Who Rates category, the players' devices could display something similar to Figure 6.17. This transparency could be a source of education as well—machine learning places us into buckets and the confidence behind this sorting is usually hidden to us. It is easy to imagine that this added feature could be used to support a game similar to the one described in Section 6.3.1 where children create hybrid animals based on these buckets. Perhaps, the challenge could be to achieve a certain level of confidence.

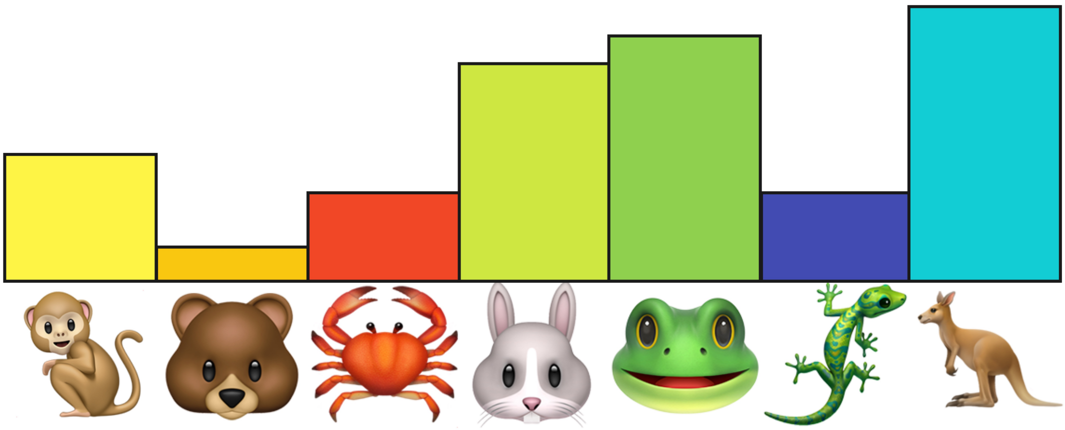


FIGURE 6.17: Graphic depiction of potential transparent machine learning model confidence buckets for Cirkus classifier

Although the model is inaccurate, it illustrates a pathway for participatory machine learning practices. Children were made aware of the intentions of Cirkus during their briefing at each workshop. They were excited to "teach" technology something new—particularly technology that could help children with SBMD. In workshops 3 and 4, children choreographed their own animal movements and had agency in how the technology should represent them. Machine learning requires lots of data, which often means doing repetitions of something over and over again, but play naturally affords repetitive actions. Using play as a vehicle for generating machine learning data is useful for the same reasons it is beneficial for health.

6.6.2 Circus arts as Physical Therapy

Circus training is a novel approach to helping children with SBMD [245]. The work presented here extends previous works and adds evidence to the value provided by this domain. Cirkus enriched the experiences and relationships between children and circus trainers because it supported playful activities that satisfied the goals of both parties. Children enjoyed playing while circus trainers valued the benefits of training locomotion and grown appreciation of the circus arts. The non-intrusive design of the technology allowed the activities to shine over the screens. Circus activities and the app made exercise fun. From improving strength, endurance, control, planning, and flexibility, Cirkus supports improving one's health through the many games the play structure affords.

6.7 Conclusion

In this work, I used participatory practices to playfully and transparently collect movement data from children with Sensory Based Motor Disorder (SBMD). I collected the movement data using Cirkus, an open-ended and flexible design probe that supports nearly any game where children move like animals. In collaboration with the largest circus group in Sweden, I ran a series of physical therapy workshops for children with SBMD and co-created games using Cirkus. I ran five workshops with a total of 30 children. I shared the resulting model and catalog of 17 games. I discussed challenges of collecting data for machine learning from children with disabilities and future plans for using models in therapy games.

6.8 My Role

I joined this research project after the initial workshops and design of technology training probes [245]. I was brought on to the project to develop Cirkus. I led the initial bodystorming session with high school interns alongside Elena Márquez Segura. Together, we made the flexible play structure by inductively analyzing the games and I mocked up the resulting interface in Adobe XD. I am responsible for the implementation, design, and networking of Cirkus. Circus trainers facilitated all of the workshops in their facility, but Annika Waern, Laia Turmo Vidal, Yinchu Li, and I were present to help. I led the school and lab co-creation workshops with the help of Annika Waern, Laia Turmo Vidal, Yinchu Li, and Paulina Rajkowska. I created the resulting machine learning models.

Chapter 7

Situated Play Design

In the previous three chapters, I shared case studies of applied research that aimed to help specific populations of people with disabilities. Through that work, I gained generalizable knowledge about how one can go about the design of technology that supports play and people with disabilities. With this knowledge, I was able to contribute to the founding of Situated Play Design (SPD), described in this chapter. This section is based on work from my collaborators and I as we formulated the SPD design method [5, 17, 27, 330–335, 335, 336]. Enhancing people's lives through play is a social good [76]. Everyday play and playfulness can have a positive impact on the well-being of both individuals and groups [84, 337], provide us with agency to be creative, enable us to express ourselves and learn [52, 338], and create opportunities for meaningful social connection [83]. Importantly, everyday play and playfulness are often situated [52]—they emerge naturally in a variety of everyday situations [52, 84, 337], tightly tied to contextual contingencies and ongoing activities, and through the creative initiative of prospective players. Drawing more on the context where play emerges and leveraging the creative capacity of users is a fruitful approach when designing for play and playfulness that integrate meaningfully in everyday situations.

Other researchers have called for well-formalized methods in design research [162] and for reimagining Participatory Design (PD) [274, 339]. Towards better supporting people's social and emotional needs, we add a call for new methods that support the design of playful interventions aimed at mundane, open-ended, everyday activities that are non-entertainment based. Situated Play Design is an extension to existing play design approaches that focuses on uncovering existing manifestations of contextual play as a starting point for designing for situated and emergent playful engagement. Arguably, the playful interactions that exist and emerge naturally as users engage in their everyday context and activities are likely meaningful to them. Situated Play Design supports designers in uncovering existing manifestations of contextual play, and using them as foundations of a design intervention, following three main steps: First, designers chase naturally existing or spontaneously emerging forms of play when interacting with users in (semi-) naturalistic settings. Second, a design intervention is created to support and enhance those forms of play. Third, this design intervention is deployed in the wild, where its impact can be evaluated. These steps can be iterated until a satisfactory design is achieved.

User involvement is well established in game and play design. But in a time when play design is becoming relevant in domains beyond pure entertainment, and play blends into everyday activity in diverse ways, we need to revisit old, and develop new, user involvement methods. Using a situated perspective and Research through Design, I present Situated Play Design (SPD), a novel approach for the design of playful interventions aimed at open-ended, everyday activities that are non-entertainment based. Like user-centered game and play design methods, this contribution leverages user engagement; like Participatory Design methods, this method acknowledges the co-creating role of end users. SPD extends those approaches by focusing on uncovering existing manifestations of contextual playful engagement and using them as design material. Through two case studies, I illustrate this approach and the design value of using existing and emergent playful interactions of users in context as inspirations for future designs. This allows for providing actionable strategies to design for in-context playful engagement.

Play beyond entertainment has become increasingly popular, both in HCI research and industry. Play and playful technologies now transcend the scope of entertainment games, and are more present in our lives [16], featuring in a variety of domains such as education (e.g., [340]), health (e.g., [341]), and the workplace (e.g., [342]). As a consequence of this broadening—of the design space of play, its relevant application domains, and the ways it blends into everyday activity—we need to revisit play design approaches.

Enhancing people's lives through play is a social good. Everyday play and playfulness can have a positive impact on the well-being of both individuals and groups [84, 337], provide us with agency to be creative, express ourselves and learn [16, 338], and create opportunities for meaningful social connection [83]. Importantly, everyday play and playfulness are often situated and contextual [16]—they emerge naturally in a variety of everyday situations [16, 84, 337], tightly tied to contextual contingencies and ongoing activities, and through the creative initiative of prospective players. For example, children act as play designers when they decide to skip the cracks on the road, imagining lava coming up through them, making the dull way home a far more interesting experience [343]. Here, play emerges through, and is sustained by, the physical properties of the asphalt and the ongoing activity of going home. But how can designers leverage this situated and highly contextual nature of play, and the capacity of users to reframe mundane situations into playful and meaningful ones? Drawing more on the context where play emerges and leveraging the creative capacity of users is a fruitful approach when designing for play and playfulness that integrate meaningfully into everyday situations.

There are general calls for well-formalized methods in design research [162] and for reimagining Participatory Design (PD) [274, 344]. Towards better supporting people's social and emotional needs, we add a call for new methods that support the design of playful interventions aimed at mundane, open-ended, everyday activities that are non-entertainment based. I propose SPD as an extension to existing play design approaches that focuses on uncovering existing manifestations of contextual play as a starting point for designing for situated and emergent playful engagement. Arguably, the playful interactions that exist and emerge naturally as users engage in their everyday context and activities are likely meaningful to them. I propose to study and leverage those interesting play activities—and their underpinning play design elements—as they emerge naturally, when users playfully engage in a context similar to that designed for, and to use that knowledge as design material.

This contribution transpired from a series of Research through Design (RtD) [2, 161, 162, 345] projects in the domain of play and playful design, sharing: (1) a focus on uncovering and leveraging existing manifestations of contextual playful engagement; (2) early involvement of users as creative partners; (3) in-context ideation activities, and (4) the usage of play and playfulness both as a design goal and design method. Here, I illustrate SPD through two case studies in remarkably different domains: a workshop that leverages various cultures' food traditions to inspire the design of playful gastronomic experiences and a re-imagining of urban spaces to support play. I use these cases to illustrate a series of actionable strategies to support this approach. I conclude with a discussion of the design implications of SPD, including the opportunities and challenges it might present, and an account of how it draws from, and extends, other approaches. This contribution can inspire interaction designers who want to design situated and emergent play interventions that work well in open-ended, everyday activities that are non-entertainment based.

7.1 Background

7.1.1 Games, Play and Playfulness: Designing at the Intersection of Play and Everyday Life

The line between play and games is fine and blurry. A well-accepted distinction between them is captured by the concepts of ludus (a structured activity that is framed by imperative conventions) and paidia (a free, improvisational activity) [84, 346]. Games usually rely on a predefined, clear, and well-set structure, composed of goals, and game rules and challenges to overcome them [66]. Play engagement emerges typically within that structure, when players embrace the game rules to overcome challenges, finding their way towards a successful outcome [338, 346]. But play can also emerge outside of the realm of games [66]. Play does not necessarily require the presence of challenges or a clear outcome [66]. Play is diverse—it can be simultaneously liberty, invention, fantasy, and discipline [84]. Although less clear than in games, there is also structure to play [346, 347]. For example, when engaged in pretend play, children often come up with house rules, such as "you're out if a bomb (balloon filled with water) explodes on you (and you get wet)."

Despite their differences, play and games share traits that are important from a design perspective: they are autotelic and self-contained activities. That is, they have a context of their own separated from other everyday activities, where playing is at focus and at stake [16, 84] and those other activities fade out. That notion of separateness is often referred to as the magic circle [66, 348]. Although some authors have argued that the notion of magic circle is obsolete, noting that play and games cannot be completely separate from the non-play world [349], we find this separation useful from a design point of view.

When designing an autotelic play activity, whether a game or another kind, designers create a new context and a set of meanings, which are maintained and continuously negotiated among players during the activity. In games, these are typically seen as exclusive to that play activity and separate from anything that is outside of the play domain [16]. Here we argue that a good integration with the out-of-play world is essential when designing playful interventions in non-entertainment contexts, where the magic circle of play blends into real life.

Play and playfulness often emerge naturally in a variety of everyday situations [16, 84, 348]. Sicart's notion of playfulness characterizes well that intersection between play and real life, "play outside of the context of play" [16]. It speaks about a specific type of play experience, "just what attracts us, [...] without the encapsulated singularity of play" [16]. As opposed to play and games, playfulness is often seen not as an activity in itself, but an attitude with which other activities can be performed. As such, it can coexist with activities other than play. Playfulness affords the many benefits of play in situations in which playing is not the only thing at stake.

The differences between games, play and playfulness are relevant to situated and emergent play design—that is, the design space of playful interventions aimed at activities that are not entertainment-based. When designing a game or any other kind of autotelic play activity, designers create a quite self-contained world from scratch that the player gladly inhabits. In contrast, this is not the case when designing for playfulness and other forms of mundane play. Playfulness moves beyond, or extends, the magic circle of a pure game, instead weaving itself into everyday life and activity. Thus, while taking the context of play and the users into account is of course useful in game design, it is essential when designing for playfulness that it is situated and emergent within mundane everyday activities. How can we support that playfulness by design? How can we design a "porous" magic circle of play that at the same time supports autotelic action—that is, play that is worthwhile in and of itself—and that also embraces players' contexts and lives? These are the key design questions this chapter addresses.

7.1.2 The Design Space of Situated and Emergent Play

In this chapter, I offer tools to support the design of situated and emergent play interventions targeted at everyday scenarios. I want to encourage and empower designers to craft compelling play experiences that are meaningful to users, and that integrate well into everyday activity. Here, I discuss previous works in the design space of situated and emergent play, where SPD can add value.

The design space of play beyond entertainment games is diverse. It includes works that respond to diverging values and different understandings of play and its role in human life. However, they all share a common trait: regardless of their motivations, they focus on reframing mundane activities and situations to be more playful, compelling, and fun. A noteworthy subset of non-entertainment play designs are those works that leverage the motivational power of play and games to support real-life productivity agendas. A well-known approach in this space is gamification [126, 350–352]), which often employs the strategy of using game elements (e.g., points, badges, and leaderboards) to make non-game activities more compelling. Gamification responds to the ultimate goal of motivating users to perform a specific set of tasks, which are necessary to achieve productive results in those activities but are not intrinsically motivating enough by nature. For example, Classcraft [340] is a digital app that motivates students to perform better at school by augmenting the learning process through game-inspired challenges and rewards.

Although popular in academia, and especially in the industry sector [352], gamification has received abundant criticism for embracing a narrow understanding of play [146, 353], for being too designer-centric [354], and for focusing more on supporting the productive outcomes of the activity rather than on the experience itself [355], which has raised ethical concerns [356, 357]. Play designers and scholars propose multiple and inspiring alternative concepts that embrace a more diverse idea of play and propose a more balanced focus between the quality of the play experience and the productive outcomes that are expected from it. Sicart makes a "call to playful arms, an invocation of play as a struggle against efficiency, seriousness, and technical determinisn" [16]. Pearce advocates for the design of productive play [358] that is tied to a purpose beyond entertainment yet meaningful to users. Kim's gameful design supports the design of meaningful user experiences that increase motivation and engagement through game thinking [359]. Nicholson's meaningful gamification [354] affords space for player-generated content that emphasizes the intrinsic value of the play experience.

Playification [143, 353] is a rather new and blurry concept [360] that draws from many of those contributions to offer an alternative to the limitations of gamification. First, it embraces a broader idea of the diversity of play, supporting playful rather than gameful behavior [143]. Second, it focuses on the design of meaningful play and playful experiences that are intrinsically compelling to players. Instead of using generalized game elements that are likely to produce extrinsic motivation to perform not-so-compelling tasks (like in gamification), playification strives to make those tasks intrinsically fun through the emergence of meaningful situated play [360]. The SPD approach can be useful to achieve this: it provides mechanisms to find out what kinds of playful engagement are already meaningful to users in their everyday context and activities, and to respond to those playful cravings by design. Thus, within the scope of non-entertainment play, interventions that support productive agendas, we align more with playification's focus on supporting experiences that are intrinsically compelling than with gamification's task-and-reward based approach.

While the idea of instrumenting play to support productive goals has an important traction in HCI, there are also important works that embrace a less utilitarian understanding of the role of play and playfulness in human life. They focus on the design of playful interventions that respond to other values than productivity, such as promoting curiosity and exploration, facilitating social connections or, more generally, supporting well-being. Gaver's ludic design leverages technology to "pursue our lives, not just work" [361]. It advocates for the design of ambiguous, open-ended technology artifacts that elicit curiosity and encourage us to be explorative and playful in our everyday routines. The idea of using technology to help people enjoy experiences we long for, and not only help them "get the chores done" [361], is shared by other designers. For example, Bekker and colleagues have explored the design space of open-ended play and playful interventions that elicit curiosity [362] and support free-choice learning through exploration [363], promote physical play [364], or facilitate social interaction [365]. The SPD approach is also relevant to those kinds of less utilitarian everyday play interventions, as they focus on augmenting everyday activities and situations through the lens of play and playfulness. Uncovering existing playful interactions that are already meaningful to users can help designers craft interventions that are more compelling and fun.

7.1.3 Influential Methods and Approaches

A key aspect of designing for situated and emergent play is that the intervention supports the emergence of meaningful play and playful engagement. Therefore, engaging users is crucial to the design process, as they are the real experts on the contexts and practices the intervention will support and augment. I am inspired by existing user involvement approaches in the design space of play and games and, more broadly, in technology design. They offer interesting insights on how to engage users and context to design interventions that integrate better in mundane situations.

A plethora of User-Centered Design (UCD) [366] methods have taught us how to incorporate users in play and game design processes (e.g., [271, 367–369]). In game design, several of the lenses within Schell's Game Design Lenses [370] are prompts to scrutinize games from the players' perspective; various works from game UX (e.g., [271, 369, 371]) suggest strategies to take users' desires into account to inform the design process; and Fullerton's playcentric approach to game design [368] offers strategies to include users in the design process, mostly to test, refine and evaluate designs. In play design, Bekker et al.'s Four Lenses of Play [367] is a "toolkit for designing playful interactions" that offers a series of lenses to inform play design and support the designer's choices throughout the design process through iteration with users. I am inspired by how those user-centered approaches iterate rapidly with users to refine and evaluate design outcomes, especially at the stages of prototyping and deployment.

Participatory Design (PD) [166, 372] methods extend UCD practices by including users earlier in the design process, before ideation starts, and giving them the role of creative partners [373]. I am inspired by PD's longstanding tradition of leveraging multi-stakeholder engagement as the core driver of a design process [164], and by many of the strategies it employs to better understand users' needs and desires, and co-create democratic solutions that address their real concerns. Participatory Design literature offers numerous strategies to better understand how users act in their everyday (e.g., Druin's insights on children's participation in technology design [373]). Instead of focusing on accessible, usable, or democratic solutions, Situated Play Design approach is primarily concerned with play and playfulness. Situated Play Design thus adds a nuance to traditional Participatory Design approaches by proposing strategies to surface existing manifestations of contextual play—called play potentials. The focus shifts from what users do to how they engage playfully in their everyday. Further, Situated Play Design gravitates towards a more flexible approach to co-creation [374]: although users take a prominent design role, solutions do not necessarily reflect a completely transparent democratic design process at all times. The designer still takes a major responsibility when selecting the observed play experiences that will drive the rest of the design process and gives new form to them in subsequent designs through varying forms of user engagement.

In contrast with Participatory Design, Situated Play Design shares play and game design's explicit focus on play and playfulness. Yet, instead of focusing on users' play preferences, SPD extends those approaches by offering actionable tools to surface existing manifestations of contextual play. This is a novel approach to co-creation in play design: proposing to study and make design-related use of play potentials—existing playful dynamics that are already meaningful in context—as the cornerstone of a playful intervention. The novelty of SPD is the proposal of chasing play that naturally emerges in real-life activities—which is likely to be intrinsically meaningful to users—as the starting point of play design. The value of SPD is that it supports, rather than disrupts, real-life activities, enriching them through enhancing those observed play potentials. It facilitates the design of interventions that afford the emergence of playfulness: the attitude that allows us to experience meaningful play within activities that are not play [16], reframing of those activities to playful ones.

While some game and play design works may already be using similar strategies to shape their design processes (e.g., works in playification [143]), a method articulating how this can be done has not yet been proposed. As a consequence, we see a lack of methodological discourse around the idea of using play potentials to design compelling playful interventions. In the next section, I present our open methodological frame to think about and better articulate participatory practices to design for situated and emergent play. It intends to empower other designers to design mundane play interventions that support the emergence of play and playfulness that are meaningful to users, and that it will encourage them to share their practices so that they can be leveraged by the broader play design community.

7.2 Situated Play Design: Chasing, Enhancing and Deploying Play

Situated Play Design emerged from a series of iterative Research through Design projects in the domain of play and playful design, sharing: (1) a focus on uncovering and leveraging existing manifestations of contextual playful engagement; (2) early involvement of users as creative partners; (3) in-context ideation activities, and (4) the usage of play and playfulness both as a design goal and design method.

SPD supports designers in uncovering existing manifestations of contextual play, and using them as foundations of a design intervention, following three main steps: First, designers chase naturally existing or spontaneously emerging forms of play when interacting with users in (semi-) naturalistic settings. Second, a design intervention is created to support and enhance those forms of play. Third, this design intervention is deployed in the wild, where its impact can be evaluated. These steps can be iterated until a satisfactory design is achieved.

Step 1: Chase the Play

Our interactions with others, with objects and with space are often—more or less explicitly—imbued with play [52]. This offers an invaluable opportunity for play designers, since playful experiences that exist and emerge through the creative initiative of users are likely meaningful to them. These existing and emerging experiences, called play potentials, could be used as foundations for design.“ Chase the play” refers to interacting with users and their context in order to better understand these playful interactions that are intertwined with the targeted design activity and context, how they emerge and unfold, and what they mean to users.

This inquiry can uncover opportunities for playful enhancements of a targeted design activity or situation.

To chase the play, different known methods in HCI can be employed, chosen to fit the design project, users, and context at hand. Useful strategies range from active interventions in direct interaction with stakeholders (e.g., using co-creation methods like embodied sketching [375]) to more passive non-disruptive observations (e.g., doing design ethnography [376]), and interventions with diverse degrees of designer involvement in between (e.g., using cultural probes [377], or interviewing with tangible tools [378]). At this stage, theory can provide lenses to understand the type of play engagement observed and the underpinning elements that support and sustain it.

Step 2: Enhance the Play

Once one or more play potentials are identified in context, the designer can proceed to enhance play and playfulness within the observed context and activity. The goal is to leverage those observed play potentials, which can be used as design target or as inspiration for other new playful experiences. They are reflected in a play design intervention, which may incorporate, or take as inspiration, observed play mechanics, play challenges, or rules of play that the users found meaningful in their context of use.

Here, the designer's expertise and repertoire of design tools, including play, game, and general design theory and practice become relevant to craft a coherent play experience [149] that incorporates and enhances those play potentials, taken as the core of the play intervention. Importantly, in SPD, play design is not theory-motivated—design expertise and theory are used to add to, take in, or augment already existing playful experiences. We have found play and game design frameworks to provide useful building blocks to craft coherent play experiences that incorporate inspirational play observations. Likewise, theories and concepts that articulate forms of play, as well as open-ended and semi-ambiguous play concepts (e.g., [379]), can help materialize our inspirational play observations. At this stage, it is important to keep design interventions open-ended and semi-ambiguous, to afford user appropriation [145, 354] in the following stage.

Step 3: Deploy the Play

The third step of our approach, deploy the play, is performed when design solutions start to materialize. Drawing on the notion that a design project does not end with a product being produced [380], we encourage designers to deploy and iterate their designs in naturalistic settings, to assess their impact in context [380] and to envision future directions. In this step, SPD converges more with traditional game and play design methods, using strategies employed by those approaches. Similarly to rapid design loops to test and iterate designs in game design [149, 368, 370], SPD involves continuous iteration and exposure with users in the wild as a way of progressively bringing a play design intervention to its final form.

Deployment, as well as the rest of the design phases, may lead to different outcomes besides an improved version of the tested design. It can also result in design after design [381] (i.e., a different design that emerges when the artifact is put in the hands of users). Last, it can lead to the formation of intermediate-level knowledge(i.e., more abstract knowledge than that captured by the design), which springs from a Research through Design process. Examples are strong concepts, experiential qualities, methods, and guidelines [382]. To deploy the play, knowledge in play-testing or user studies are useful, as are play and game design theories (e.g., [370, 379, 383] to analyze this deployment; they can provide lenses through which we understand the design's impact.

7.3 Case Studies

7.3.1 Playing with Food Cultures Workshop

To illustrate the use of SPD, I co-organized a workshop aimed at designing technology inspired by food traditions of various cultures [336]. The result of the workshop was an annotated portfolio [336] of play-food potentials that could help promote playful and social engagement in food practices. The portfolio emerged from a one-day workshop where we played with and analyzed a collection of 27 food traditions from diverse cultural backgrounds and historical periods. I highlight play forms and experiential textures that are underexplored in Human-Food Interaction (HFI) research. This contribution is intended to inspire designers to broaden the palette of play experiences and emotions embraced in HFI.

Digital technology increasingly permeates human food practices. More and more, digital gadgets and services mediate food interactions, (e.g., VR dining experiences like Sublimotion[1], smart ovens like June[2], online grocery shopping like Instacart[3], and food intake monitoring apps like MyFitnessPal[4]. The research field of HFI not only produces such gadgets, but also studies the impact of technology in food practices to inspire future designs. A recent mapping study [27] shows a dominant trend in HFI research to make food practices more efficient, safe, and convenient. Yet, too much focus on optimizing interactions with and through food may compromise the socio-cultural, emotional, and material dimensions of our food lives. Food practices are far more than an act of survival: they are vital for our social lives and expressions of culture. Human Food Interaction technologies should respond to these less tangible, but no less important, needs.

[1] https://www.sublimotionibiza.com/
[2] https://juneoven.com/
[3] https://www.instacart.com/
[4] https://www.myfitnesspal.com/

In HFI research, play is increasingly used to enhance interaction with food [384]. Play-inspired interventions afford fun and social food experiences. Play designers and theorists (e.g., [15, 84, 383]) have long held that play is a rich and diverse phenomenon that can take multiple forms and experiential textures: exploration, fantasy, creativity, fellowship, and humor, among others. However, the emerging field of Playful HFI has a recurrent focus on a narrow range of play forms [384]. It often gravitates towards the aesthetics of meaningful choice [15]: play experiences that are common in mainstream videogames, such as challenge, competition, or task completion. Exploring a broader range of play forms enriches the design and research space of Playful HFI.

In this case study, I present findings from a design-led workshop exploring playful food traditions from diverse cultures and historical periods. We looked for forms of play that are ingrained in culture, such as rituals and traditions. These forms of play and their underlying cultural significance may be an invaluable source of inspiration for future playful technology. I share our selection of 27 playful food traditions in the form of an annotated portfolio [385], and identify their underlying play potentials. I discuss recurrent design qualities, interaction mechanisms, and types of playful experiences, as well as how these elements may inspire future food technology design. By surfacing play potentials that are embedded, but sometimes hidden, designers may be inspired to broaden the palette of play experiences and emotions embraced in HFI.

The workshop brought together 18 participants with diverse cultural and professional backgrounds. Participants came from, and had significant lived experiences in, countries including: Spain, US, Canada, Australia, Denmark, France, Germany, Israel, Colombia, Philippines, China, Turkey, Portugal, Belgium, the Netherlands, and the UK. They came from industry and academia and practiced within interaction design, design research, gamification, computer science, business development, and HCI. Participants brought to the workshop a total of 27 traditions from their culture, community, or family. We collectively experienced, discussed, and analyzed these contributions using food and food-related materials, as well as a diverse set of design research strategies. These strategies included analytical tools (e.g., analyzing traditions through theoretical frameworks of play [16, 66, 84, 337, 383, 386] and HFI [27, 384]) and embodied design research methods (e.g., modifying the traditions through embodied sketching [329]). The tools allowed us to experience and investigate what made the traditions fun and how they could facilitate interesting social experiences. We worked in small groups, then shared insights and collectively clustered the play traditions and our findings into recurrent play potentials. This analysis was again iterated after the workshop by the authors, to challenge and solidify the insights from the workshop. The result is a set of play potentials to inspire future Playful HFI technology designs.

7.3.1.1 Playful Food Traditions

FIGURE 7.1: Food traditions from multiple cultures used during the workshop.

All workshop participants provided at least one tradition in their workshop position paper; several provided more (up to 4). The result was a rich variety of traditions from multiple cultural backgrounds, which differed in scale and national and international popularity. For example: the Christmas Cookie Contest is a family tradition I provided; the Kale Tour, a regional seasonal tradition from the German region of Lower Saxony; Pimientos del Padrón, a Spanish tradition popular all over the country; and Trick or Treating, a North American tradition that has become a global phenomenon. All traditions submitted by participants, including original photos and unfiltered descriptions are available[5] and shown in Figure 7.1.

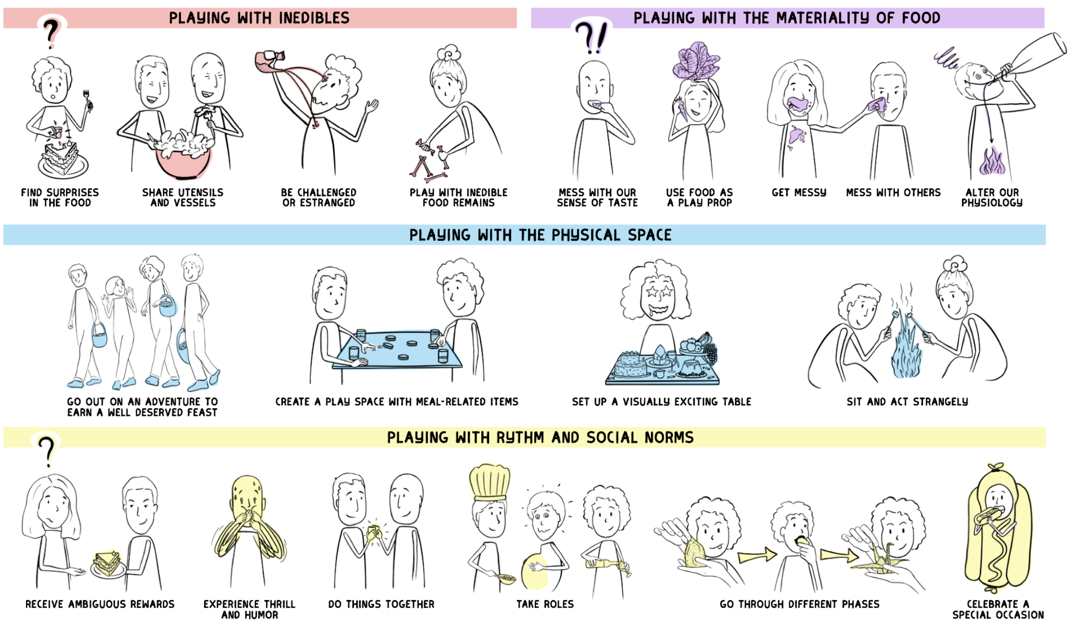


FIGURE 7.2: Summary of play potentials.

Four overarching categories emerged from our analysis, shown in Figure 7.2, which I illustrate through a selection of traditions below. The categories speak of the design materials used to support the play potentials: food; inedible materials; the physical space; and the rhythm and social norms of the activity.

Playing with the materiality of food There are different ways in which traditions leverage the material richness of food to give us chances to be playful. Some

[5] https://bit.ly/2XvFVXO

traditions are fun because they challenge and allow us to get messy. They can also give us chances to be subversive and mess with others, which allows us to laugh together and strengthen bonds. In other traditions, the fun comes when eating or drinking has a clear effect on our senses and state, altering our physiology (e.g., we lose dexterity after drinking alcohol), or making us experience thrill by messing with our sense of taste. Finally, we have also seen traditions where the source of fun and enjoyment is using food as a play prop, e.g., as a silly-looking object that can be used to dress up and decorate.

La Calçotada (Catalonia) exemplifies how food experiences are more fun when they are somewhat messy and challenging. In this seasonal celebration, people gather to grill and eat a type of onion called “calçot”. Eating calçots is difficult: their size and elongated shape make them hard to put in one’s mouth. Quite often, the sauce they are dipped in ends up dripping and falling onto one’s face or clothes, making the whole party laugh. *La Calçotada* also shows how much fun it can be to use food to mess with others. As people’s hands get dirty from removing the burned peels of calçots, they often start to sneakily paint each other’s faces. Entire meals are infused with thrilling social play—prank or be pranked!

Touhu (China) is a game with origins in traditional Chinese archery rituals. The fun comes when drinks mess with the players physiologically. The game requires players to throw arrows from a set distance into a large vase. If the arrow misses the vase, the player has to drink some wine. Here the drink is not only the reward but a key element of the experience: the more drinks, the less dexterity, and therefore the more laughter and fun.

The *Kale Tour* (Lower Saxony, Germany) is a tradition that celebrates the beginning of the kale harvesting season with a hike through the local forest followed by a kale meal in a traditional German restaurant. One of the funniest parts of the tradition is to see the Kale King wearing a crown made of kale—a cruciferous vegetable. The highlight of the meal is the announcement of the new Kale King who is selected by the king from the previous year. For the award of the royal title, the new king receives a crown made out of kale. Food is thus used as a play prop, in this case a costume.

Playing with indedibles: utensils, Vessels, and props Food-related items that do not—or at least should not— belong in our bellies are often integral to how we play and eat. In our collection of traditions, there are several examples of how inedibles can shape playful food experiences. For example, sharing utensils and vessels as we eat, drink, or cook can lead to emergent playful interactions between people. Utensils and vessels can also be used to challenge or estrange while eating or drinking—this can be especially fun when one is in the spotlight. Another example of playing with inedibles is hiding and then finding surprises in food, which can create intrigue and expectation about when the hidden item will be found and by whom. Inedible food can also lead to playful engagement in food practices, allowing us to play with inedible food remains before or after eating.

The *King's Cake*, also known as *Roscón de Reyes* (Spain) or *Galette des Rois* (France), is a European tradition that is enjoyed at epiphany, a religious celebration that honors the biblical figures of the Three Wise Men. In this tradition, a king figurine and sometimes a bean is hidden inside a cake. Made with a variety of dough types, toppings, and fillings, *King's Cake* is a tradition where hidden surprises promote play: whoever finds the king figure or bean in their slice of cake, will be treated like the Royal Highness all day. Depending on the regional variation, the king is immune from washing dishes, will have food and drinks brought to them, and/or will get to wear a paper crown. In some cultures, the recipient of the hidden bean becomes the butt of all jokes for the rest of the day and often has to pay for the cake. The addition of these small hidden objects in a cake opens up many opportunities for social play, including: competing for pieces, placing bets on who will find them, abusing the king's power, or the inevitable teasing of the bean recipient.

In *Kamayan* (Philippines) people gather around a table lined with banana leaves and eat a communal meal with their hands. Using the hands to eat in this way—from a shared vessel or surface (the table)—inevitably leads to social interaction. When enjoying *Kamayan*, it is not uncommon for family and friends to feed each other as an act of love. The tradition creates many opportunities for emergent playful behaviors: it involves messy eating, fighting for the "best" parts, or tricking others into thinking you are trying to feed them, only to feed yourself in the last second.

El Porró (Catalonia) is a tradition of drinking wine out of a specialized vessel that streams the wine out of a small nozzle. This risky challenge results in many stained shirts. Veterans of the tradition are able to sing or say tongue twisters while drinking from *El Porró*. The further out one holds the vessel, the longer the stream and the more impressive the feat. This tradition brims with opportunities for playful engagement, including: racing to be the first to finish the wine, singing the most clearly while drinking, or spilling the least wine as participants become increasingly inebriated.

Playing with the Physical Space In the traditions in our collection, we found examples where fun derives from the physical configuration of the space in which food activities take place. That includes not only the physical properties of the space, but also people's movements within it, or the placement of the food materials and diverse food-related objects. We found traditions that elicit fun by inviting participants to sit and act strangely, bringing them together in an uncommon space and inviting them to act in ways that are different from a regular meal. In other traditions, fun comes from setting up a visually exciting table: placing food and utensils in decorative ways to inspire awe, a sense of plentifulness, and wonder. We also see traditions where the table is not deliberately set up to be playful from the onset, but people playfully appropriate the meal space. This is the case of emergent games and contests where people create a play space with meal-related items, re-signifying the table, the floor, or another food-related surface. Finally, we see traditions that expand the boundaries of the meal space by extending it to the outdoors and inviting people to go out on an adventure and earn their well-deserved feast.

In *Hot-pot* (China), a boiling pot of broth is laid out in the center of a table, together with an abundant selection of uncooked meat and vegetables. The combination of food ingredients and food-related objects creates a table configuration that is colorful and exciting. This configuration encourages diners to be playful: it invites them to explore and experiment with their food choices and to personalize their dining experience. Further, the shared pot of broth brings diners together, forcing them to cook together and inviting them to prepare pieces of food to share.

Las Chapas (Spain) is a game people play with bottle caps. The game can take different forms, e.g., inspired by football, players create an improvised football pitch with the objects they have to hand, and use bottle caps as the ball to score goals with their fingers; similarly, inspired by car races, players can create a racing track and compete to knock their bottle cap to the finish line first.

Trick or treating (North America) also requires people to go out and earn their food. It involves knocking on neighbors' doors to receive candy. Playfulness comes in the stops, but also throughout the entire festive route.

Playing with rhythm and social norms In our collection, we see several traditions where fun derives from changes in the rhythm and social norms that regulate the food activity. In some occasions, that takes the form of a short, fast-paced activity where people experience thrill and humor. Such activities often lead to bloopers and laughter. Thrill, fun, and laughter can also come from receiving ambiguous rewards either as a prize or a punishment. For example, in some traditions, rewards obtained by participants (e.g., becoming the king in the Kale Tour) may have a downside that is known and agreed upon by the group (e.g., having to treat others to a round of drinks or being responsible for next year's meal). In other traditions, fun, laughter and, more generally, social bonding comes as people start doing things together, e.g., cooking, eating, moving, or saying things in coordination with other people.

In cookie-making traditions (various cultures), making food with others is a core source of enjoyment. Sharing a table, the food materials, and the food preparation tools brings people together and can lead to emergent social play. Cookie-making allows for different roles and different shares of responsibility. For example, adults can push the process forward by preparing the dough, while telling children what to do (and what not to do). These roles can afford playful appropriations and transgressions. For example, in one participant's family cookie-making tradition, children found ways to sneak around adults to eat the cookie dough as it was being prepared, something which the adults had told them not to do. In another participant's family tradition, teenagers often decorated the cookies in ways that they knew would provoke, and perhaps discomfort, the adults in the family.

Krembo (Israel) is an extremely light meringue resting on a cookie, topped with a very thin layer of chocolate and wrapped in a thin aluminum foil. *Krembo* affords a three-step experience: First, removing the foil wrapping in one piece, without damaging the foil or the thin layer of chocolate is popularly challenging. Second, the material properties of the sweet afford creative ways of eating it, leading to various theories and intense debates on which is most effective and pleasurable. Finally, the wrap is commonly used to create tinfoil artworks, which can be used as play tokens in ad hoc games.

7.3.1.2 Discussion

The traditions featured here have become ingrained in people's lives as expressions of culture. The annotated portfolio [336] of play-food potentials they inspired thus has a strong cultural grounding: it presents playful experiences and interaction mechanisms that have evolved over time and have become, in different ways, part of people's lives. Arguably, this is proof that these play-food potentials are relevant to people, that they represent things that people enjoy.

The traditions described in our portfolio extend the current state of play in HFI. They show different ways in which we might engage with our food beyond the aesthetics of meaningful choice, e.g., exploring the ingredients, flavours and textures in a Hot-Pot table setup; being creative in a cookie-making contest; laughing with one another as we eat spicy Pimientos del Padrón; or strengthening bonds as we paint each other's faces with the ashes from eating "calçots". These and other experiences we present here illustrate how play-food experiences can facilitate social bonding in ways other than challenging and competing against each other, which seem to be valuable yet often overused social interaction mechanisms in Playful HFI.

The portfolio illustrates how play-food engagements can: (1) afford enjoyable interactions with and through food materials; (2) leverage inedible food-related objects to promote social connection; (3) create new play spaces where social engagement takes place; and (4) regulate the rhythm and social norms of a social situation to enrich our shared experiences around food. It also shows how playing with our food can highlight the materiality of food as a key component of a food experience. I argue that this is an important contribution, especially relevant given emerging trends in technology innovation that seem to increasingly distract us from experiencing rich material engagements, with food and beyond. For example, social media use at mealtimes often draws attention away from the food and other diners and onto the screen, may disrupt our enjoyment of food by letting it get cold, may prevent others from eating until a photo is taken, or spoil the surprise element of a restaurant menu through posting pictures online.

These play potentials can inspire designers to embrace a more diverse notion of what playing with food might look like. Perhaps more importantly, the play-food potentials coupled with digital technology offer the means of augmenting food experiences through the addition of nuanced twists to routine, culturally-grounded interactions. These, in turn, can support agendas that are important in technology design, such as: affording embodied experiences and meaningful tangible interactions, leveraging playfulness and gamefulness to improve experience design, scaffolding social engagement, or promoting behaviors in motivational design. Designers interested in exploring how such issues relate to the space of food practices could be inspired by our work.

Designers of gamified apps for healthy eating may learn from how certain traditions highlight the value of, and make exciting, foods that may not be particularly interesting to a diner, e.g., chestnuts or kale. They might learn from how traditions motivate people to go outdoors, to find intrinsic (rather than extrinsic) pleasure in walking or exercising before or after a meal, and thus position eating within a larger landscape of well-being practices. Digital applications and systems designed for behavior-change purposes related to sustainable consumption might look at how traditions add value to food remains and food packaging by inviting people to make creative use of these materials, e.g., using them as play props or making artworks with them.

This portfolio of play-food potentials may also inspire future designs with technologies of a more nascent nature. For example, VR- and AR-augmented dining might learn from how traditions use visually rich table layouts to afford experiences of awe and wonder and encourage exploration and customization. Food-related social wearables could be inspired by how traditions appropriate food and food-related materials to create curious wearable play props, adding performativity and laughter to the food activity. Food-related tangible and ubiquitous computing may be inspired by how traditions use inedible objects to add hidden surprises to our food, or how shared utensils and vessels encourage people to cook and eat together, thereby strengthening social bonds. Researchers interested in immersive interactive spaces may also learn from looking at how traditions invite people to use the space in different ways than usual, and act in ways that differ from a regular meal.

7.3.2 Re-imagining Urban Spaces with Play

Here, I present a co-design exploration into the potential of technology to playfully re-signify urban spaces [330]. We created a speculative catalog of urban tech and used it to facilitate multi-stakeholder discussions about the playful potential of smart cities. The lessons from our co-design engagements embody different people's ideas of how tech might and might not support rich forms of urban play, and contribute to ongoing efforts at exploring how to playfully reconfigure our cities. I present a list of inspirational play potentials of urban spaces (i.e., playful things already people do, and enjoy, in the public space), a portfolio of speculative ideas that show how tech might help to realize that potential; and a discussion of stakeholders' responses to these ideas. This work can provide designers with inspiration and actionable advice for cultivating forms of urban play that cater to people's socio-emotional needs.

Smart cities are often presented as opportunities to increase urban efficiency [387], optimize infrastructure [388] and, thus, spur the economy [389]. Less attention is paid to how tech may or may not contribute to enriching the socio-cultural fabric of cities [390, 391], especially in commercial implementations [392]. This as a missed opportunity when it comes to cultivating stimulating urban spaces where people can flourish. Inspired by existing works exploring less techno-centric (e.g., [391, 393–395]) and increasingly playful (e.g., [396–400]) urban futures, we have a design research agenda of exploring the potential of play to contribute to the social, cultural, and emotional sustainability of urban spaces.

Research suggests that cities should be far more than productive [397, 399]. Our streets, parks, and town squares are far more than tools at the service of our economy: they are made up of moment-to-moment passing interactions between human beings and, as such, they should be socially rewarding, culturally stimulating, and emotionally rich. While there is value in designing technology that makes our cities more efficient, designers should also pay attention to the impact that technology has on people's mundane experiences of their day-to-day. Here we contribute to an emerging body of work that explores how to do that by adding an element of play to our streets. In particular, our study investigates the inherent playful potential of urban spaces and speculates as to how we could design interactive technology that helps to realize it.

Here, I present the outcomes of a speculative [19] co-design [374] exploration of the playful potential of technology to reclaim the socio-emotional significance of the urban space. This contribution is two-fold: First, I provide a list of play potentials of urban spaces: a set of urban play forms that we observed in the ordinary urban practices of people in different parts of the world. As instances of people's natural, spontaneous, playful urban behavior, we present those play potentials as a valuable inspiration source for designers. Our second contribution is an annotated portfolio [385] in the form of a catalog of speculative playful urban technology ideas. The concepts featured in the catalog build on, embody, and instantiate the aforementioned play potentials to illustrate how they may inspire novel urban tech. The insights from this work allow us to provide actionable advice for developing playful urban technologies that are sensitive to people's social, emotional, and cultural needs. Overall, I believe our work empowers designers to embrace increasingly playful and socio-emotional approaches to urban innovation, providing both inspiration and guidance to facilitate that move.

7.3.2.1 Play Potentials of Urban Spaces

				Pose in urban spaces			Out of the ordinary interactions w/ urban infrastructure					Out of the ordinary interactions between people					Creative disruptions		Stream exciting urban events		
ID	Link	Date posted	Post description	#1- Pose in front of a relevant object/landmark	#2- Pose next to an out of place object	#3- Pose in strange ways	#4- Explorative	#5- Silly performance	#6- Embodied performance	#7- Overcome challenges	#8- Collaborate/coordinate	#9- Leave messages for other people to find	#10- Communicate at a distance	#11- Massive celebration moments	#12- Be nice to others	#13- Scare and/or prank	#14- Appropriate urban space artistically	#15- Customize how you appear in public	#16- Document fun things	#17- Find alternative beauty	#18- Stream self-imposed challenges
1	https://www.instagram.com/p/B0yG7Jjhr5C/	08/05/19	Someone's foot is covering the C on a label saying No					1									1				
2	https://www.instagram.com/p/B034MfchT-a/	08/07/19	Two boys hung up a poster of them at McDonald's					1									1				
3	https://www.instagram.com/p/B034VSyBvEX/	08/07/19	Friends took a picture of themselves and put it in frame	1													1				
4	https://www.instagram.com/p/B1Qdtn2I-tf/	08/17/19	Oven left on a street									1									
5	https://www.instagram.com/p/B1nXcbnI4T9/	08/27/19	Writing on the ground saying "lou lou was here"									1									
6	https://www.instagram.com/p/B1rqM8soJfl/	08/27/19	A book of funny public signs									1									
7	https://www.instagram.com/p/B1uPfTxoAYm/	08/29/19	A machine that prints out short stories for people									1	1								
8	https://www.instagram.com/p/B1ujC_poed-/	08/29/19	Person pointing at a landscape and creating a horse					1					1								
9	https://www.instagram.com/p/B2dmh78ItBo/	09/15/19	Balloon looking objects that are punchable																1		
10	https://www.instagram.com/p/B3BKipzIRQm/	09/25/19	Cashier singing song with their machine					1													
11	https://www.instagram.com/p/B3BLIyUIsVZ/	09/29/19	Yellow house with a sign that says it is a honeycomb									1					1				
12	https://www.instagram.com/p/B3ItxBxokhQ/	10/02/19	Two people surfing and high fiving							1			1								
13	https://www.instagram.com/p/B3fELN5INVK/	10/11/19	A building that lights up and lets people play tetris								1										
14	https://www.instagram.com/p/B3fUy9ShFG8/	10/11/19	Dolphin that is splashing people who do not want to be					1											1		
15	https://www.instagram.com/p/B4Pxh5SI5gX/	10/30/19	Group of kids counting down the time at a cross walk				1	1			1										
16	https://www.instagram.com/p/CAx35FkH0eX/	05/29/20	Man playing the drums at the back of a car (?) while ve					1		1											
17	https://www.instagram.com/p/CA0Un48jaw7/	05/30/20	Woman doing yoga barefooted at the bottom of a large	1																	
18	https://www.instagram.com/p/CAznS9LJ2kx/	05/30/20	Woman doing handstand splits on the middle of a bridg	1																	
19	https://www.instagram.com/p/CA0gmvlDY0x/	05/30/20	Woman balancing on top of a rock structure at the top	1																	
20	https://www.instagram.com/p/B-M-56gquHU/	05/26/20	Two kids lying on the ground where there are unicylces														1			1	
21	https://www.instagram.com/p/CAgRBRzlVuz/	05/22/20	Kid laughing and hanging off a tree branch.			1															
22	https://www.instagram.com/p/B7ZCHoDBvsg/	01/16/20	Eyes are put on tree branches to make them look like					1									1				
23	https://www.instagram.com/p/B4VZX8bHYuU/	11/01/19	Kid with leaves on his face leaving space for eyes and					1													
24	https://www.instagram.com/p/B0-rb5EnO6e/	08/10/19	Little girl playing with sand and trying to make it into a				1														
25	https://www.instagram.com/p/B_NdkGeg4n5/	04/20/20	Little girl with cat ears playing with mud while laughing				1												1		
26	https://www.instagram.com/p/Byf25t3ncZ0/	06/09/19	Two kids looking surprised as a puddle sprays water a				1														
27	https://www.instagram.com/p/CBZPbhoA7A9/	06/13/20	Little kid holding a chicken in his overalls while laughin	1																	
28	https://www.instagram.com/p/CBVuiq_BaCX/	06/12/20	Little kids posing in a suitcase looking at bubbles			1															
29	https://www.instagram.com/p/CBPs_W7hE3A	06/10/20	Two kids standing on a fence laughing with each other	1																	

Figure 7.3: Screenshot of the first 20 datapoints of our dataset of social media posts featuring playful urban behavior.

This case study began with a contextual exploration of the playful potential of urban settings. We created a collection of social media posts (made by other users) and examined it to identify recurrent forms of playful engagement within the public space. Social media is rife with posts that display everyday ways of being playful. Many of the posts people produce every day could potentially be inspirational from a design perspective: they feature mundane playful situations that could be used as starting points for ideation. Because of that, we thought social media might be an interesting play-chasing tool—a particularly useful one in the context of urban technology design, since much of social media content features events that take place in public spaces. For five weeks, a team of six researchers spent 3-5 hours a week looking for posts that displayed playful urban behaviors. We focused on Instagram and TikTok due to their leisure-focused and visual nature. We collected posts on a shared Google spreadsheet, including: a link to the post, a short description, the publication date, and (if needed) a note indicating why it was inspirational, shown in Figure 7.3. We collected 383 posts in total. Then, we used inductive thematic analysis [401] to find play potentials in our collection. After two rounds of refining our themes—we discussed and contested each other's codes to ensure inter-coder reliability—we settled on a final set of codes and analyzed all the data accordingly. The result was a list of play potentials—ways in which people already engage playfully within the city—each of them instantiated by several social media posts. We clustered the play potentials into five larger categories, shown in Figure 7.4 based on affinity. Here, I describe those categories, their play potentials, and a set of posts that exemplify them .

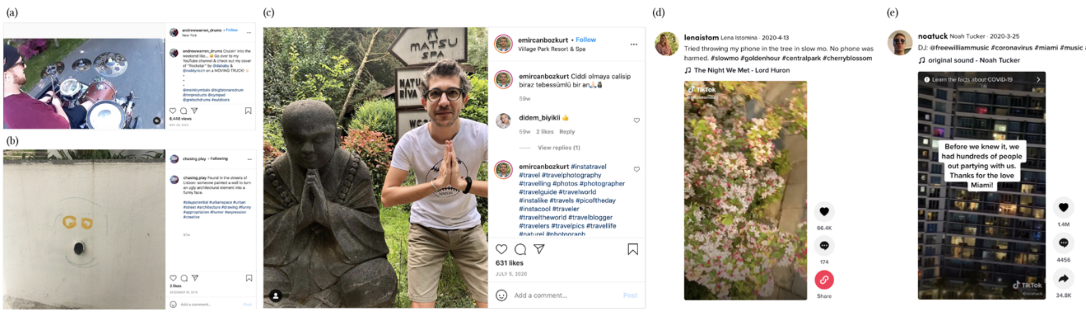


FIGURE 7.4: Examples of posts in our collection, representing the 5 themes we saw.

Out of the ordinary interactions with urban infrastructure (287 posts). A recurrent theme in our collection was interacting with public infrastructure in out-of-the-ordinary ways. We found five play potentials related to this category:

1. "Stop to interact with public infrastructure" (58 posts). For Example, by admiring a piece of art projected on the façade of a building[6].

2. "Perform in public in silly, unusual, or creative ways" (73 posts). For example, playing drums from the trunk of a moving car[7].

[6] https://bit.ly/3l5by2U
[7] https://bit.ly/36rwBIX

3. "Using their bodies in synchrony with elements of the urban space" (80 posts) through dance or any other sort of planned movement (e.g., a street performer dancing inside a metro car using the car's infrastructure as a support[8]).

4. "Overcoming improvised physical challenges" (54 posts), using urban infrastructure as the playground (e.g., people parkouring[9] or kids climbing on a fence and hanging onto it[10]).

5. "Collaborate to better the state of something or someone in the public space" (22 posts). For example, engaging with an art installation that encourages people to volunteer to take care of plants[11].

Posing in urban spaces (127 posts). Another recurrent theme in our collection was the act of posing in or around relevant public objects or spaces. We identified three play potentials under this theme:

1. "Posing in accordance with relevant objects or landmarks" (61 posts). For example, a man interacting in silly ways with a fountain as he is being recorded[12] or a man mimicking a statue next to him[13].

2. "Posing next to objects that are out of place" (20 posts). For example, people posing in front of objects that they sneakily placed[14].

3. "Posing in unconventional ways" (46 posts). For example, jumping off of a sculpture[15] or risking falling from a tree by sitting on it for a photo[16].

[8] https://bit.ly/34lS9UC
[9] https://bit.ly/3l9fwI0
[10] https://bit.ly/3n8oaZ7
[11] https://bit.ly/3ne8mnq
[12] https://bit.ly/2ET02rV
[13] https://bit.ly/2GdPi8q
[14] https://bit.ly/3jqrCvM
[15] https://bit.ly/30sfGCe
[16] https://bit.ly/2GjbcXK

Streaming exciting things that take place in public spaces (125 posts). Here, the focus was not so much on urban activity itself, but on the act of sharing it with others. We saw that behavior manifest in different ways:

1. "Documenting exciting things they saw in the street" (74 posts) For example, through a TikTok compilation of street art[17].

2. "Documenting elements of a public space to find alternative beauty in them" (19 posts). For example, capturing ordinary urban spaces in ways that showed them in a different way (e.g., a post where the author throws her phone up into tree blossoms while it is recording to produce a slow-motion video[18]).

3. "Streaming self-imposed challenges" (32 posts) so other people could witness them (e.g., a girl challenging herself to move between two points without touching the floor[19]).

Creative disruptions of the public space (81 posts). Another theme in our collection had to do with creatively disrupting public settings:

1. "Appropriating the urban space artistically" (57 posts), which can be done both carefully (e.g., painting a face on a wall using a bush as the face's hair)[20], or spontaneously (e.g., turning an ugly architectural element into a funny face with a doodle)[21].

2. "Customizing the self" (24 posts): changing one's public appearance to provoke others' reactions. An example is a post where the authors customized their electric skateboards to look like a tiny police car or a dinosaur, thereby attracting other people's attention[22].

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[17] `https://bit.ly/3cQncMh`
[18] `https://bit.ly/3cSff99`
[19] `https://bit.ly/34cJMKU`
[20] `https://bit.ly/2EUWKVh`
[21] `https://bit.ly/2Gnzwrk`
[22] `https://bit.ly/33pSd6y`

Out of the ordinary interactions between people (64 posts). The last recurrent form of playful interaction we saw in the data is the act of interacting with others in out-of-the-ordinary ways. We found different kinds of interpersonal urban interactions with a playful potential:

1. "Leaving messages on public spaces" (21 posts): finding creative ways of communicating with non-present others, whether that be through art (e.g., a doodle or mural) or text (e.g., a billboard with a joke or a name written somewhere) for someone else to find. For example, a post that shows a message someone left on the pavement so that other pedestrians would read it[23].

2. "Communicating at a distance in somewhat silly ways" (17 posts). For example, a lady yelling a funny phrase out of her window and someone responding back[24] or people from a train waving at passersby they never met before[25].

3. "Sharing celebratory moments" (4 posts), For example, an entire apartment complex gathering on their balconies to dance to music[26].

4. "Being nice to others" (8 posts).For example, a man saying good morning to strangers in the street[27].

5. "Harmless pranks and jokes between strangers" (14 posts), For example, scaring people by pretending to accidentally topple boxes on them, knowing that the boxes are attached[28].

We synthesized the findings into a shorter list that was more actionable for designers—one that would not be too long or complex to be used as a starting point for

[23] `https://bit.ly/33p0JTu`
[24] `https://bit.ly/3l6UeKN`
[25] `https://bit.ly/3cWg68T`
[26] `https://bit.ly/2Gb9Dv3`
[27] `https://bit.ly/34jlsHl`
[28] `https://bit.ly/3ipvDPN`

ideation. To surface those aspects of our findings that had most inspirational potential from a design perspective, we clustered the play potentials by affinity. The result is a list of 15 play potentials of urban spaces (featured in Figure 7.5): playful things people already do (and seem to enjoy) in the public space. We present them as contextually grounded starting points for ideating playful urban technology; we suggest they can inspire designers to envision technology-mediated playful urban experiences that intertwine well with, and enrich, the socio-emotional texture of our cities.

7.3.2.2 Catalog of Speculative Urban Technologies

Building on our play potentials, we set out to speculate how urban tech could respond to them. We began with a first ideation round where six researchers worked independently to generate early ideas of urban tech that embraced at least one of the play potentials. We produced 25 ideas, collected them on a slideshow, and expanded them at a subsequent brainstorming session. Next, two designers examined the collection of early ideas to identify themes. The themes were discussed in another meeting, where we settled on seven emerging design directions that we found interesting and that resonated with the findings from our play-chasing work. Then, we took two weeks to concretize each design direction into 1-2 urban technology design concepts, taking the early ideas as a point of departure. We refined the resulting concepts at a final meeting where we discussed each other's work. Throughout, we kept track of how our ideas related to the play potentials (shown in Figure 7.6). Finally, we mocked up our early concepts into a Catalog of Speculative Playful Urban Technology Ideas. We frame it as an annotated portfolio [385] of speculative design ideas [19] highlighting interesting and socio-emotionally desirable forms of technology-mediated urban play. Importantly, by speculative here, we do not necessarily mean ideas that are technically unfeasible or extravagant; rather, they are inspired by [354, 402–404]; we used speculation

PLAY POTENTIALS OF URBAN SPACES

#1 Admire the urban space
It can be fun to find unexpected, surprising, hilarious, visually stimulating things in the street. Designers should think about how their interventions could capture people's attention and provide an experience of wonder.

Source: scraping social media

#2 Stream exciting urban occurrences
People enjoy documenting interesting things they find around the city (e.g. beauty, action, surprises). Designers should think about how to allow people to document urban occurrences to share lived experiences and express themselves creatively.

Source: scraping social media

#3 Discover the invisible
It can be fun to explore the hidden cultural subtext that conforms the socio-cultural fabric of a city. Designers should think about how to enable and encourage people to discover tacit urban knowledge to become familiar with an environment.

Source: play & culture workshop

#4 Fill the gaps
Fantasizing about things we know very little about can be fascinating and mind-absorbing. Designers should think about how their playful urban designs might help people tp imagine and fantasize with the backstories of others surrounding them.

Source: play & culture workshop

#5 Temporal decontextualization
There is something exciting about learning about the real or imagined history of an urban space while physically present. Designers should think about how to enable people to share and learn the stories that took place in a city.

Source: play & culture workshop

#6 Pose performatively
People enjoy posing in strange ways around landmarks, statues, or out-of-place objects. Designers should think about how to enable and encourage playful kinds of posing experiences that are fun for both those who pose and those around them.

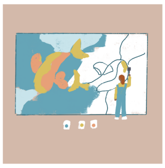
Source: scraping social media

#7 Performative behaviors
Some people enjoy doing things that are noticeable (e.g. silly, creative, or otherwise remarkable). Designers should think of ways to augment urban spaces in ways that people feel safe to be performative for their own enjoyment and to amuse others.

Source: scraping social media

#8 Customize the self
Some people also enjoy wearing attention-grabbing clothing, wearables, lights, and costumes. Designers should think about how to facilitate experiences where people can enrich their public appearance.

Source: scraping social media



#9 Hack the street
Streets can be a canvas for personal expression: to make art, share ideas, and communicate through messages. Designers should think about how to enable citizens to appropriate the urban space and use it to advance their creative/expressive agendas.

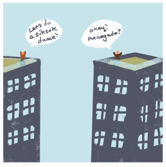
Source: scraping social media + and play & culture workshop

#10 Connect with strangers
Urban spaces are social connection arenas. There is something playful about looking at other passers-by as treasures to discover. Designers should think about how to prompt people to accidentally meet strangers and initiate new connections.

Source: scraping social media + play & culture workshop

#11 Asynchronous communication
There is an element of fun, mystery, and excitement in leaving messages on public spaces for other people to find. Designers should think about how to augment the urban space with technology that enables people to communicate asynchronously.

Source: scraping social media



#12 Communicate at a distance
It is fun to connect with others who are visible but at a distance, knowing that it'll be a brief and lightweight interaction. Designers should think about how to afford distanced and time-bounded social experiences that are exciting and fun.

Source: scraping social media

#13 Massive celebrations
There is something exhilarating in being part of a massive celebration. Designers should think about how to use technology to enable moments of collective celebration, bringing strangers momentarily together to cheer and share joy.

Source: scraping social media

#14 Prank strangers
If done safely, it can be fun to prank strangers. Designers should think about how to facilitate lightweight forms of urban pranking that are harmless (physically, emotionally, socially) and fun for both the pranker and the pranked.

Source: scraping social media

#15 Urban challenges
Some people enjoy self-imposed urban challenges, e.g. jumping on certain tiles, or crossing the street in <n seconds. Designers should think about how to afford small, spontaneous challenges that add a bit of spice to people's ordinary urban movements.

Source: scraping social media + play & culture workshop

FIGURE 7.5: Our list of urban play potentials, identified through two interventions: scraping social media and a play and culture workshop. A plain text version of the list can be accessed online at `https://bit.ly/30VQS9d`

as a means of enabling co-design discussions around technology futures that are plausible from a technical perspective but not yet a commonplace part of people's imaginary. For an optimal representation of the design ideas, I refer the reader to the original catalog[29] .

Design directions	Design ideas	Play potentials: #1 - Admire the urban space	#2 - Stream exciting urban occurrences	#3 - Discover the invisible	#4 - Fill the gaps	#5 - Temporal decontextualization	#6 - Pose performatively	#7 - Performative behaviors	#8 - Customize the self	#9 - Hack the street	#10 - Connect with strangers	#11 - Asynchronous communication	#12 - Communicate at a distance	#13 - Massive celebrations	#14 - Prank strangers	#15 - Urban challenges
Augmented infrastructure for authoring urban experiences	Share-a-song									●	●	●	●		●	
	Moody lights						●			●	●	●	●		●	
Parallel (in)visible realities	A Mad Hatter's world			●	●			●	●		●		●			
Spontaneous instigators of strange(r) connections	Ready, steady, cross!							●			●			●		●
	Dancing the lights						●	●			●			●		●
Large-scale urban toys	Building art	●								●		●				
	The selfie photoshoot		●				●		●					●		●
Portals of imagination	Sensorial memory bench			●	●	●					●	●				
	Silhouettes	●		●	●	●					●	●				
Local lore modules	Scavenger hunt plaques	●		●	●	●		●		●	●	●			●	
	Local whispers	●		●	●	●				●	●	●				
Shared canvases for collective grandeur	VanGo		●		●											
	Fountain of whispers	●			●					●	●	●		●		

FIGURE 7.6: Summary of ideas (and underlying design directions) included in the Catalog of Speculative Playful Urban Technology Ideas, linked to the play potentials they respond to. An accessible version of the table, including the 13 catalog ideas and the early collection of 25 ideas, can be accessed at: https://bit.ly/30VQS9d

This case study illustrates how speculative co-design methods (and, in particular, the Situated Play Design approach) can help to envision playful tech that enriches people's urban experiences in ways that create meaningful inefficacies [405] that enable a resemantization [400] of the urban space. It builds on and extends a rich body of existing work in the space of playable cities by paying close attention to contextual playful practices people already enjoy in the public space. As such, it provides powerful bottom-up inspiration for designers and researchers whose agenda is to use playful tech to enrich our cities socio-emotionally. Our work sheds light on playful things people already enjoy doing within the city—ones that are likely meaningful to them and that, as such, may have inspirational value. By chasing play potentials in urban spaces, we can uncover play forms people find meaningful and enjoyable in public settings. Those play potentials can then be

[29] https://bit.ly/30TETZd

used as starting points to inspire urban technology design, leading to ideas that align with playful practices citizens feel excited about. Such an approach can help designers craft playful experiences that resonate with a city's socio-cultural fabric, and thereby contribute to realizing (rather than disrupting) the city's inherent playful potential.

The work done in this project contributes to an ongoing shift in values behind smart city innovation—arguably, a necessary one. We present it as inspiration for designers interested in developing urban technology that contributes to shaping public spaces where individuals and communities can flourish—productively, yes, but also socially, emotionally, and culturally. That inspirational provocation comes in the form of a two-fold contribution: First, the play-chasing phase of the project allowed us to uncover a series of playful practices people already do and enjoy in urban spaces. These play potentials can inspire the design of technologies that afford contextually meaningful forms of urban play; they can help designers to ground and examine their ideas and reflect on whether they respond to playful and social practices citizens long for. Second, the Catalog of Speculative Playful Urban Technology Ideas provides a set of half-baked design concepts that illustrate how the above play potentials can be used to guide technology design. As such, it can inspire designers at the early stages of their work, focusing them on affording types of urban experiences that are socially, emotionally, and culturally stimulating.

These contributions potentially give rise to smart city innovations that transcend techno-solutionism. The ideas we foreground respond to urban experiences people seem to long for, though they are hardly embraced in commercial smart city implementations. However speculative, the combination of these ideas and the multi-stakeholder reflections about them can help designers to be mindful of playful and social practices people already enjoy within their city—in ways that would support (rather than disrupt) the playful potential inherent in an urban space.

Importantly, these insights are bottom-up (i.e. they respond to views and existing urban practices of average citizens) and socio-emotionally focused (i.e. they center on supporting rich, delightful urban experiences). As such, they challenge approaches to smart city innovation that, as [390] notes, are often top-down, utilitarian, and techno-centric.

Some ideas in the catalog may raise tensions and even be problematic from a societal perspective—e.g., Silhouettes may be at odds with the privacy of passersby, or Dancing the light may enforce a playful attitude to those who are not in the mood for it. The aim with the catalog was not to avoid those tensions, but rather to surface and tackle them through the lens of a variety of people's sensitivities. By engaging diverse people to comment on, criticize, and further develop the catalog ideas, we can augment those ideas with a bottom-up layer of critical thinking, which we argue can help designers to think more carefully about the playful interventions they design for the urban space.

In this case study, I presented a SPD study investigating the playful potential of smart cities. Through a series of speculative co-design engagements, we explored how playful technology might add socio-emotional value to our public spaces and experimented with design qualities that might support that move. The outcomes of our study are two-fold: First, we identified and made design use of a series of playful practices people already seem to engage in and enjoy in urban spaces, which we present as play potentials that can inspire the design of playful urban technology that affords contextually meaningful experiences. Second, we developed a Catalog of Speculative Playful Urban Technology Ideas to experiment with how different kinds of technology might help to realize that playful potential, and to create a diverse set of future imaginaries around this space. This work contributes to ongoing efforts at playfully reconfiguring urban spaces, in the domain of technology design and beyond, and extends them by putting the focus on commonplace, playful urban practices that can be used as contextually grounded starting points for design. This work aims to inspire and empower designers and researchers to continue to strengthen the palette of existing playful smart city interventions, in ways that are more contextually sensitive and socio-emotionally rich.

7.4 Reflection

The main contribution of Situated Play Design is that it empowers designers to identify and understand emergent playful dynamics that already exist in context—and are thus likely to be meaningful to users—and to support and enhance them by design. Importantly, SPD does not exclude, but rather builds on, complements, and extends many design strategies often employed in User-Centered Design, Participatory Design, or game and play design. We build on UCD by including users in the design process but consider them active contributors rather than inspirations or evaluators. We see users as creative partners [406], while in UCD their role is to indirectly influence the designer's work. Instead of limiting user input to playtest sessions or the refinement of existing prototypes, Situated Play Design encourages designers to leverage users' tacit knowledge of their own realities from the moment a design process starts.

SPD is thus inspired by Participatory Design [166, 372], a longstanding tradition of leveraging multi-stakeholder engagement as the core driver of a design process [164]. Yet, instead of focusing on accessible, usable, or democratic solutions, Situated Play Design is primarily concerned with play and playfulness. Participatory Design literature offers strategies to better understand how users act in their everyday, e.g., Druin's insights on children participation in technology design [406]. Following a recent call to reimagine Participatory Design [274, 344], Situated Play Design adds a nuance to traditional PD approaches by proposing co-creative strategies to surface existing manifestations of contextual play—what we call play potentials. The focus shifts from what users do, to how they engage playfully in their everyday—that move responds to a contemporary need to design technology that responds to people's social and emotional needs, and not only to support productive agendas. Further, in SPD, although users take a prominent design role, solutions do not necessarily reflect a completely transparent democratic design process at all times.

SPD shares play and game design's focus on play and playfulness. Yet, instead of focusing on users' play preferences per se, SPD extends those approaches by offering actionable tools to surface existing manifestations of contextual play. This is a novel approach to participation in play design: we propose to study and make design use of play potentials—existing playful dynamics that are already meaningful in context—as the cornerstone of a playful intervention. The novelty of SPD is the proposal of chasing play that naturally emerges in real-life activities as the starting point of play design. The value of SPD is that it supports, rather than disrupts, real-life activities, enriching them through enhancing those observed play potentials. It facilitates the design of interventions that afford the emergence of playfulness: the attitude that allows us to experience play within activities that are not play [16], reframing of those activities to playful ones.

While some game and play design works may already be using similar strategies to shape their design processes, e.g., works in playification [143], a method articulating how this can be done has not yet been proposed. As a consequence, we see a lack of methodological discourse around the idea of using play potentials to design for situated and emergent play. This chapter addresses the gap in methodological discourse by visualizing the need for methodology contributions in this space and offering an open frame where participatory play design practices can be shared, combined, and critically reflected upon.

SPD is thus an open methodological frame aimed at supporting emergent playful design practices. Rather than enforcing a unique set of practices, SPD gives pointers to a diverse set of flexible tools that can help designers design for situated and emergent play. SPD is thus aligned with a generative understanding of Research through Design [161]—it structures design just enough to make it approachable. It does not attempt at simplifying design or eliminating uncertainty. Instead, it empowers designers to navigate—and leverage—that uncertainty. Situated Play Design is an inclusive and evolving framework that encourages designers to share best practices and thus diversify the set of tools available to the community. My case studies demonstrate that, while part of one SPD umbrella, they use different methods. Critically, reflecting on those cases through the lens of SPD allowed for unpacking our strategies so that they can be used by others hereafter.

7.4.1 Challenges and Limitations

User engagement in play design presents challenges. First, many game designers have noted that it is often difficult for people to tell what they will find fun before they try it out (e.g., [171]). While that might be a barrier in the design of entertainment games, we argue it is less problematic in the design of situated and emergent play interventions. Games are often closed systems that are separated from—and significantly more abstract than—the player's everyday context and routines. In situated and emergent play interventions, playfulness intersects with—and often builds on top of—those routines. Importantly, users are the ultimate experts on their own routines. With co-creative methods like those described in our case studies, designers can help users describe what they think is fun, and what might be, and discuss this in interplay with their playful engagement with their context and routines.

Another common source of skepticism towards co-creative approaches to play design is the effort they require. Rusch explains that participatory approaches to game design are limited by how costly it is to prototype a videogame [171]. In game design, while early low-fi prototypes are often used by design teams to facilitate rapid iteration cycles [368, 370], playtesting with real audiences usually happens at an advanced stage of the process [368] and employs hi-fi prototypes that resemble the "final experience" [171]. Developing hi-fi prototypes requires remarkable time and specialized skills. Once that time has been spent in development, it is hard to take several steps back and rethink structural design decisions. Here, we argue the problem is less present in the design for situated play. While in video games, a new world is built from scratch, in situated and emergent play designs, the world of play is the users' context. The core design materials already exist: the users, their space, the objects in that space, and the situations that emerge in the interplay between all of those. Using those materials as a starting point, and leveraging co-creative methods such as mock-ups [407], embodied sketching [329], object theater [408], tangible tools [374], or Wizard of Oz [233], designers can co-design low-fidelity prototypes in-situ with stakeholders in a lightweight way. In fact, those explorations can even be useful once the core mechanics of a system have already been determined. While such methods are already used by many in game and play design (e.g., [409]), we suggest using them earlier in the process and involving real audiences.

Another challenge to co-creative processes in play design, and in particular in our SPD approach, is the same reason that makes them powerful: the situated nature of their outcomes. SPD produces context-dependent knowledge that might not be applicable beyond the situations explored. Importantly, the aim of SPD is not to inform the design of playful systems that work in all possible scenarios. Rather, it supports the design of situated artefacts that genuinely address the idiosyncrasies of specific scenarios. As noted by Bertelson et al., there is value in designing for the particular as it "can enable us to capture the richer and more complex nuances of a particular situation or user, hence also directly challenging the assumptions we make as researchers" [410]. That being said, the outcomes of different SPD explorations can be combined to produce intermediate-level knowledge [382] that responds to a variety of scenarios, thereby broadening the space of applicability of a design. That, in combination with user-generated content strategies such as [145], might help designers create interventions that are applicable beyond one single domain.

7.5 Conclusion

In this Chapter, I outline SPD as an approach that extends current play design frameworks by empowering designers to identify and understand meaningful playful dynamics that exist naturally in context, and to support and enhance them by design. It supports the design of playful interventions addressed at mundane, open-ended, everyday activities that are non-entertainment based, where the line between real-world activity and the magic circle of play fades away. The approach focuses on capturing the emergence of play in semi-naturalistic settings and using those observations to inform the design of the key aspects of playful interventions that work well alongside such activities. Situated Play Design supports, studies, and makes design use of play and playful engagement:

1. That emerges naturally as users interact
2. That is deeply grounded in a context similar to that designed for
3. Early in the design process

Playfulness is latent in many everyday situations, ready to emerge—SPD can help support and enhance it, and that can help technology designers better respond to people's social and emotional needs. To make the approach accessible to other designers, I unpacked SPD as a three-phase iterative process—including chasing, enhancing, and deploying play—and provided actionable mechanisms for each of those steps. To illustrate our approach, I described how SPD might unfold in two case studies from my own work in different areas within the design space of play. Finally, I offered a discussion on the novelty of our approach, as well as on the challenges and opportunities it might pose.

To conclude, SPD builds on existing contextual play potentials to create playful interventions that resonate with these experiences and respond to contextual idiosyncrasies. It thus responds to a need to design for everyday play and playful engagement beyond entertainment games, which can have an impact on individual and collective well-being and is therefore a desirable social good. In this chapter, I make accessible a series of situated and emergent user involvement mechanisms we found useful when designing for situated play. I hope that it will also encourage the play design community to expand the—currently limited—set of methods that support the design of playful interventions addressed at mundane, open-ended, everyday activities that are non-entertainment based, with the aim of supporting people's social and emotional needs.

7.6 My Role

I co-founded SPD with Ferran Altarriba Bertran, Elena Márquez Segura, and Katherine Isbister. My insights from working on the case studies presented in the previous three chapters enabled me to contribute to the formation of this method. Situated Play Design was primarily led by Ferran and, while I collaborated on the case studies presented in this chapter, Ferran led the work. I took the lead on some integral SPD work, but that text makes up the contents of Chapter 9.

Chapter 8

DREEM

8.1 DREEM

DREEM is a design method I co-founded based on generalizable knowledge gleaned from working on assistive technologies described in Chapters 4-6 and my experience co-founding Situated Play Design (SPD), described in Chapter 7. After the founding of SPD, I was interested in developing a design method intended to specifically benefit people with disabilities. In this work, I explored how online content[1] created by people with disabilities can be utilized in assistive technology research and design. Empathy building is a common stage of design thinking and human centered design research in which researchers "set aside their own assumptions" to get to know user's real needs [411, 412]. This stage is used to uncover research questions or design problems. Merriam Webster defines empathy as "the action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another without having the feelings, thoughts, and experience fully communicated in an objectively explicit

[1] Content and Media are used broadly to mean any created artifact.

manner" [413]. Empathy has long been considered an important component of participatory design as well as research processes.

When used correctly, I believe empathy building can be a powerful first step before beginning participatory design with people with disabilities. A common approach to empathy building is to imagine yourself in someone else's shoes (i.e., what would it be like if I was 10 feet tall?). This approach is not appropriate in the context of learning about people with disabilities. Researchers and designers working with disabled people should be careful to use empathy building to better understand "being with" rather than "being like" or "vicariously living through" users as the definition above suggests [291]. To be clear, it is not appropriate or effective to do empathy building for people with disabilities through "trying on" their disabilities [414]. In this work, I explored how immersing oneself in the content created by disabled individuals can be used to build empathy. It is a way to begin understanding communities before engaging directly with community members during later stages. Taking on this investigation of the community before (but not as a substitute for) working directly with users can be useful for building a basis for appropriate future interactions.

This could be a small step toward alleviating "the potential over reliance and under acknowledged use of people with disabilities for their 'access labor'..." [3, 415]. Indeed, methods such as iterative design require a large number of participants [416]. Researchers can take on some of this initial labor by engaging with and celebrating the pre-existing cultural labor of disabled people [417]. Researchers can build authentic understandings of the needs of populations with disabilities as a precursor to any type of participatory or community-based work without putting undue access work on the community.

This chapter examines how close readings of media produced by people with disabilities can lead to productive empathy building and the discovery of authentic, meaningful research agendas. I present our nascent method for building this empathy called DREEMing (Disability-Related Empathy from Existing Media), which builds on other influential methods from various disciplines described in the Background (Section 8.2), contemporary critiques of the SIGACCESS field discussed in the Motivation (Section 8.2.2), and our own experience of empathy building through three case studies presented in the Case Studies (Section 8.4). DREEM is a 4-step process that I describe in Section 8.5—with actionable tips and insights for how to find appropriate content and develop authentic research agendas. Finally, I discuss DREEMing's novelty, relevance, recommendations for working with research assistants, challenges, limitations, and future work.

In summary, this work builds off of prior research in this space [291, 411, 412, 418] and the primary contributions are a novel 4-step method for building empathy with disabled people via media created by people with disabilities, and materials for using the emerging method, including trainings, data logging templates, and a tool for visualizing close readings. We found that actively engaging with media made by people with disabilities is an opportunity for new researchers to learn about these communities and working with disabled people.

8.2 Background

In this section, I begin by discussing the motivations behind DREEM, which include sharing labor with people with disabilities, technosolutionism, contemporary critiques posed to the SIGACCESS community from disability studies scholars, and documented challenges of employing co-creative, participatory methods with people with disabilities. Next, I discuss the methods and approaches that inspired us and influenced DREEM.

8.2.1 Prior work Social Media Data Collection in SIGACCESS

In recent years, we have seen similar strategies for utilizing online content to inform research decisions in accessibility and assistive technology. We hope to build upon this existing work with our methodological contribution. This includes analyzing podcasts centered on blind technology [419], YouTube videos including those with physical disabilities and mobile devices [420], amazon reviews from those with vision impairments [421], Facebook groups of blind parents [422], engaging with content on TikTok to inform playful design for people with disabilities [17], and many more.

8.2.2 Motivations

A recent survey of ASSETS and CHI accessibility work showed that only 16 methodological contributions (3.2% of all) have been made to the accessibility community since 1994 [3]. **What does it mean to create a method that values disabled contributions?** The guiding principles toward this value are:

- *Labor 8.2.2.1* Honor the work that is already done and value contributor's time. Make disabled contributions meaningful and accessible.
- *Technosolutionism 8.2.2.2* Don't come to the table with a solution already in mind.
- *Authenticity 8.2.2.3* Disabled people are not medical patients.

8.2.2.1 Labor

There are many successful examples of co-creating with disabled people (e.g., [21, 94, 97, 118, 119, 169, 170, 176, 182, 192, 423–425]). However, we must acknowledge the labor required by people with disabilities in both designing and living with existing assistive and accessible technologies. In designing methods that center around contributors with disabilities, labor should be carefully considered. A danger of iterative processes, such as participatory design, is how much work we ask of participants who we are trying to help [416]. Similarly, access labor refers to the work that people with disabilities are required to do in order to have their access needs met [3, 415, 417]. There are concerns such as 'informant fatigue' (e.g., being asked too often to share repeated personal details [426]) and 'forced intimacy' (e.g., being required to divulge deeply private information in order to gain access [427]). This can also mean maintaining friendly relationships with caregivers [428], requesting specific accommodations from event leaders, or the everyday work of living with a disability in an ableist world [11]. I posit that DREEMing ahead of participatory sessions can alleviate the need to use precious time for learning the basics about a population and instead focus on actual co-design work—giving them meaningful ownership as co-designers rather than collecting overly personal information.

The high rates of assistive technology abandonment are due, in part, to the inability of designers to take populations' perspectives into consideration [181, 429, 430]. Here, there can also be a labor cost to using poorly designed technology after it has been developed, as described by many disabled writers (e.g., Forlano [431] or Weise [432]). For example, Forlano, a professor of design who sometimes writes about her experience with type one diabetes, must frequently remove herself from meetings and gets woken up in order to recalibrate her automatic insulin pump [431]. If user input has proven to be valuable to designs where the contributions of populations with disabilities are included [176, 177], why then are many systems designed without leveraging it? Kujala suggests that these challenges stem from arriving to the table with a prototype before doing appropriate ground work [183]. Doing groundwork with existing media made by people with disabilities can alleviate many of these concerns for the initial stages of research exploration.

Cultural labor is the organizing and creative work done to contribute to a particular culture such as disability cultures [4, 417]. Cultural labor can be in many forms of advocacy including books (e.g., Nothing About Us Without Us [4]), legislation (e.g., the Disability Act [433]), or shared accounts (e.g., Resistance and Hope [434]). Existing cultural labor is what DREEM relies on.

8.2.2.2 Technosolutionism

Too often, able-bodied scholars wave their techno-magical wands to try and fix problems they believe people with disabilities face [4, 435]. A prime example of this phenomenon was beautifully articulated by Karen Nakumura during the 2019 ASSETS keynote where Nakumura argued, among other examples, that people who are blind do not want smart white canes because technology dies inconveniently, needs regular charging, is heavy, expensive, and can become a spectacle [436]. The white cane is already well designed, so why fix something that already works when there is much real work to be done? Nakumura also posited that if the engineers had simply asked a blind person whether or not they were interested in a smart white cane, they would have quickly moved on. Additionally, an important use of DREEM is to train scholars new to the assistive technology field such as undergraduate researchers in the hopes of circumventing some of this thinking early on in their careers [418].

8.2.2.3 Authenticity

Over a decade ago, ASSETS scholars called for the use of a critical disability lens while designing and developing assistive technology for disabled individuals [290]. This call has only strengthened in the proceeding years, with an emphasis on allowing for more co-design and co-research with disabled people [291–293]. To summarize the concern, the majority of assistive technology devices and applications are rooted in medical discourse. That is, disability is an inherent problem in the body and must be "fixed" or "normalized" by intervention. Using a more socially-oriented lens, such as those found in disability studies, emphasizes the social context and environment as *creating* disability by denying access to particular body configurations [294–296]. There is also an ongoing conversation in disability studies that examine disability as a culture and identity [437], which also leads to a re-examining of the *purpose* of that technology for those designing assistive technology. Given this concern about the discourses that influence the design of assistive technologies, it has become even more important for researchers to acknowledge the needs of the disabled individuals the technology is meant to help. DREEMing can potentially offer a lens into the sociocultural fabrics of disabled communities.

8.2.2.4 Novelty

As discussed above, there has been much discourse on how the SIGACCESS community needs to do better in regards to technosolutionism, authenticity, and inclusive design, but to our knowledge there have not been actionable processes towards addressing these issues. DREEM is a bridge between contemporary critiques and actionable steps towards building research agendas that will support a more inclusive and accessible society. DREEM is intended to support new scholars and those interested in contributing to the SIGACCESS field.

8.2.3 Influential Methods and Approaches

As mentioned in Section 8.2.2, there are relatively few methodologies designed specifically for use by the SIGACCESS community. Accessibility research draws on existing research methods such as those from human computer interaction, computer science, design, psychology, and sociology. In this section, we discuss the multidisciplinary methodologies that informed the creation of DREEM.

8.2.3.1 Close Readings

Close readings are the careful, deliberate observation of an artifact [438]. Close reading is about *seeing* what is there (and not there). It is about mindfulness, noticing, and reflection [438]. Close readings afford the wandering mind to ask questions about what is and is not present and reflect on the possibilities in a larger context. The method originated in literary studies, and is typically conducted on text. Close readings can also be applied to other designed artifacts such as games (e.g., [439]), software (e.g., [133]), videos, film, and images. Close readings are typically conducted by scholars in the humanities, but there is potential for designers to leverage close readings more broadly. If a close reading is the mindful, disciplined reading of an object with a view to deeper understanding of its meanings [438], then it has the potential to help us understand the experience of living with a disability more deeply. In short, close readings can help us build empathy. DREEMing relies on close readings and provides suggestions on how to find relevant media.

8.2.3.2 Netnography

Netnography is an online research method originating in ethnography and is often employed by social scientists and anthropologists [440]. Instead of focusing on typical embodied phenomena in ethnography such as body language, netnography focuses primarily on the context of online media such as text and multimedia [441]. Netnography is typically conducted on a smaller scale than sentiment analysis run on large data sets and provides more nuanced behavioral findings than automated software. Netnography is a subset of digital ethnography, with netnography focusing more on the individual encounters across social media. Since Netnography uses spontaneous data and conducts observation without intruding online users, it is regarded as more naturalistic than other approaches such as interviews, focus groups, surveys and experiments [442]. These online community members often share in-depth insights on themselves, their lifestyles, and the reasons behind the choices they make [440]. For DREEM, these communities are populations with disabilities and the media discovered provides a basis to conduct a close reading for empathy building.

8.2.3.3 User-centered Design and Participatory Design

These related design approaches strongly emphasize a need for user involvement in all stages of design. From exergames for wheelchair users [97] to speech therapy [24], virtual reality for teaching people with developmental disabilities to identify emotions in others [96], and robots for physical rehabilitation [143], technology can effectively be designed with and for people with disabilities. For facing the next generation of big issues that matter, all stakeholders should participate in the design of technology they will use [274]. DREEM fits within the larger umbrella of participatory methods by leveraging existing cultural work to educate researchers prior to co-design sessions so that they can be more effective and appropriate. DREEM is not a replacement for participatory work, it is a precursor.

8.2.3.4 Reflective Journaling

Reflective journaling is an ethnographic strategy that is conducted by relating one's own experiences and contexts to the material one is investigating. This strategy "actively engages the student with the content in an intensely personal way" [443]. Reflective journaling helps learners to construct their own knowledge rather than passively absorbing it [444]. This work in critical self reflection is already highly present in the HCI design community [445–447] A reflective journaling approach may employ a standard written essay format, a diary log, or handwritten annotations as well as more artful forms such as plays, art, music, and poetry. We have found reflective journaling to be an essential part of DREEMing because it has the potential to reveal the writer's process of understanding, internalized assumptions relating to the data, and to be a space to congeal ideas that are forming while in this exploratory stage. In conjunction with close readings, these reflective practices generate intermediate-level knowledge that is well situated for developing new understandings of spaces and developing empathy.

8.2.3.5 Inductive Thematic Coding

Thematic analysis allows researchers to explore themes (overarching categories of common data) with the aim of understanding emerging phenomena and communicate findings with other researchers [448]. Inductive coding is especially relevant for the creation of new research agendas because it allows us to find novel areas, problems, and gaps to focus on. Inductive thematic coding is relevant to DREEM because it offers a grounded and established basis for generating research questions and communicating findings.

8.3 Method

The research questions that inspired the development of DREEM are:

RQ1: *How can assistive technology researchers and designers utilize media made by disabled people in their work? (DREEM)*

RQ2: *What types of insights does DREEM offer?*

RQ3: *How can scholars adopt DREEMing efficiently?*

For *RQ1*, we experimented with a methodological framework which we call DREEM (Disability-Related Empathy from Existing Media). The process, motivations, and results of developing the DREEM framework are detailed herein. *RQ2* is related to the *value* of DREEM, which we illustrate through our case studies. We use this section to describe how we conducted DREEMing with a team of researchers towards iterating on the method itself and building the case studies. For *RQ3*, we use reflective journals presented in the discussion section to share the insights, limitations, and value of DREEMing.

To develop the DREEM framework we began with these 3 steps:

1. Discover Existing Media
2. Close Reading
3. Reflective Journaling

We took a research through design approach [2, 161] and employed DREEM while iterating on its implementation through three case studies which we present in the following section. In this section, I describe the process of employing DREEM with four undergraduate research assistants. In the following sections, I discuss its final evolution.

Prior to recruiting undergraduate research assistants, the senior research team, who designed the initial version of DREEM, completed steps 2 and 3 on *The Power of Choice*[2] independently. Afterward, we collaborated on tweaks to the data collection process and included our findings as a case study in the training materials we developed. We recruited four RAs through department newsletters and by advertising in classes we teach. Our research flier is included in an editable

[2] https://www.youtube.com/watch?v=B1sWtT-wShI

form in the supplementary materials online[3]. We accepted all applications. We then used *When2Meet* to find a time everyone was available for an onboarding session. The hour-long training described the motivations of the work, instructions on how to carry out the work, and expectations. An editable version of our training slides are available in the supplementary materials online[4]. We asked undergraduates to reflect on their interest and confirm whether or not they wanted to participate as a collaborator. RAs then used our DREEM form (available in the supplementary materials as an editable google form online[5]) to independently and asynchronously conduct steps 1-3. We had a recurring weekly check-in where we discussed progress, research directions, and reflections as a team. Our specific case studies were born from exploration and interest-driven directions led by the RAs. After three weeks, interns participated in the inductive data analysis and helped us construct the write-up for the case studies presented in this paper.

8.3.1 Ethics

A tricky element of our research is discovering existing content on social media and the ethical implications of researching on these platforms. Our data collection method closely aligns with *Netnography* [440], which has established ethical guidelines [449]. These include the notion of public versus private information on social media, whether to anonymize or cite participants, and informed consent. Kozinets argues that ethical procedures must be decided on a case-by-case basis contingent upon the topic matter, the research purposes, and the research approach of the particular *netnography* [440]. Some platforms such as Facebook and Instagram have varying levels of security and privacy settings for content and profiles that complicate what is truly public. Researchers using platforms with privacy settings must respect what is considered public and not. Bassett and Kozinets argue that

[3] `https://tinyurl.com/DREEMRecruitment`
[4] `https://tinyurl.com/DREEMTraining`
[5] `https://tinyurl.com/DREEMForm`

when the internet is used as a "megaphone-like" public broadcasting medium [450], we can thus perceive it as a form of cultural production, in a similar framework to that of the print media, broadcast television, and radio, where we should cite the source so that broadcasters can be credited for their work [449, 451]. Sometimes content posted online is ephemeral such as temporarily available stories. To respect creators' wishes, we did not include these media in our case studies. Because this research is minimal risk and fits the notion of public broadcasting online, we provided links to the original content in our published materials to respect the creators' (ongoing) decisions concerning public access to the videos. *Netnography* of public archival content (not active research interventions such as interviewing) such as the media discovery methodology employed in this research would be unduly complicated with informed consent because the manual, non-automated access by researchers of public information should be acceptable without special permissions or actions, [452] and removing information from unreachable broadcasters would undermine researchers' ability to contribute to society [449]. Therefore, we included all applicable data scraped in our supplementary materials and make every effort to represent the content in this publication respectfully and in a positive light. Finally, our data was manually discovered without any automated system or software and is not used for commercial purposes, and therefore, at the time of writing to the best of our knowledge, adheres to the terms of services of these platforms.

8.4 Case Studies and Value

In this section, I present three exploratory case studies which use the DREEM framework. I then present a survey of researcher learnings from conducting these case studies. All authors contributed to close readings for the case studies, but the quotes within this section are anonymized.

Research team collaborators were free to explore any media form of interest, platforms, and communities—as long as the content was created by a disabled person. After an inductive analysis, the close readings and reflections were sorted into eight emerging non-mutually exclusive themes: ableism, aesthetics of personal expression, autism, traveling with a vision impairment, everyday tasks with a vision impairment, Tourette syndrome, mobility, and communication, which are all available in the supplementary materials online[6]. I chose to present three in this chapter to evaluate our initial version of the DREEM method, including ableism, Tourette syndrome, and Beauty Products and Aesthetics.

8.4.1 Ableism Case Study

In this case study, three researchers close read five media sources around the topic of "ableism." Two of those sources were text-based articles, one TikTok video, and two YouTube videos. Each of these media were addressing and describing different aspects of ableism encountered by the creators. The content ranged from educational to emotional and personal.

The first article described the author's experiences during a year of lockdown due to the COVID-19 pandemic. The second article described the experiences of disability in a hospital setting. Both addressed issues of ableism towards them as a result of disability and the impact of that ableism on their respective experiences. It is worth noting that for the second article, the researcher was unable to finish the close read as it was "really emotional" and, therefore, they chose to put it away for the time being. We will discuss the difficulty in doing this type of analysis in the Discussion (Section 8.6).

The YouTube videos were longer-form content that was more educational and explanatory in nature. One was about traveling in Paris with disability and the

[6] https://tinyurl.com/DREEMData

other was a video log (vlog) educating about ableism. The third video was on TikTok, and therefore only one minute long, and was a personal description of how a student had experienced discrimination for both their gender and disability from their math professor.

For these five media, three had completed reflective journals reflections. All three reflections were about the researcher's epiphanies and new understandings about disability and ableism after having close read the media. For example, one researcher wrote, "[a]bleism and other discrimination could stem from the lack of education." Another researcher wrote, "systemic Ableism does not disappear even when top officials try to implement a fair approach."

The close reading of content about ableism allowed the researchers to analyze and reflect on information about discrimination of disabled people firsthand. For example, in the video about the student experiencing discrimination from their professor, the researcher reflected on the situation and asked some rhetorical questions in their close reading. For this researcher, they reflected on the use of particular language by the creator,

> "The professor responses and belittles the creator whenever they make a make a mistake or a question. The creator also relates this situation to being treated a like a child. Do they make this comparison because they feel like they are smaller or helpless? There are other ways to describe being condescended or put down, and them deciding to compare to how a child is treated by an adult is interesting."

While discourse around those with disabilities being treated like children is common in disability communities, this was something new for the researcher doing the close reading. Later in the same video, the researcher comments in their close read,

> "It seems ironic that this school has an Office of Disabilities, and yet this professor still acts this way, which points to the fact that the office has not yet action for this professor's behavior. Has no student or other staff reported the professor? I wonder why."

In this one minute TikTok video, the researcher has come upon a number of different effects of systemic ableism. Future research in this direction would most likely uncover more of this type of findings. Doing this close reading first before approaching members of the disabled community allows this researcher to begin to have an understanding of some of the barriers that those with disabilities face.

8.4.2 Tourette Syndrome Case Study

I chose to include this case study because it offers an interesting perspective on how the affordances of various social media platforms can affect the types of insights DREEMing can offer. Overall, 65 out of 70 of the close readings and reflective journals related to Tourette syndrome across seven media sources were completed by one highly motivated undergraduate researcher. The media sources include a personal website (hosting a blog, *Youtube* videos, tweets, and a shop awareness around Tourette syndrome), five *YouTube* Videos, and three TikToks.

The first media source is a personal website, called *TicTastic!*, written by a 14-year-old musician who attends school, surfs, blogs, bakes, and has Tourette syndrome and obsessive-compulsive disorder. Close reading a website that hosts a variety of media surrounding one individual's perspective offered a depth that was unique to our learning.

> Seeing a new and darker side of her experience made me realize and remember that not all publicity/media coverage will correctly and fully represent a disability (or anything really).

This question of *true* representation of media coverage is interesting—and we were particularly puzzled by some media on *TikTok*. While there were sources of wholesome media on TikTok related to Tourette syndrome (e.g., a couple playfully forgiving each other after a tic caused accidental physical contact), there was also videos that made us ponder the disabled creator's intent. For example, one creator created a highlight reel of their tics while cooking pasta and many of the comments seemed offensive—why did the creator post this? Was it for comedic relief, authentic lived experience, visibility, or something else all together? Unanswered questions are why DREEMing can promote empathy and foster new partnerships.

TikTok's short videos offer quick flashes of insight—whether they are rants, humorous moments, or viral challenges—but they often leave us with more questions than answers, which is not counterproductive. *Youtube* on the other hand, affords much longer videos and more content, but the general population may be less inclined to spend their time watching a longer *YouTube* video as compared to the negligible time it takes to watch one *TikTok*. In a reflection by one of the researchers discovering content on *YouTube*, they were surprised at the patience of the content creator's friends and family:

> It was great to see the positive reactions in the moments of accidents, and that showed that these people understood how and why tics happen. And it seems to remind the importance of education and how that allows people to empathize and understand. It also makes me think that educating people on disabilities would help to create a better environment and society without ableism.

YouTube was also an effective platform for us to discover subgroups of the Tourette community—particularly those who are also gamers. One of the videos showed a woman playing the popular game, *Among Us*, a multiplayer mobile game where players finish tasks on a spaceship while impostors try to eliminate the crew mates and players try to deceive each other in an interactive *whodunit*. The researcher reflected on the possible effectiveness of using games as a platform for increasing disability visibility and education. When using DREEM on various platforms, it is important to consider each platform's affordances as well as the intended audience for the content (e.g., a video for fellow members of a disabled community or a video for the general public).

8.4.3 Beauty Products and Aesthetics Case Study

I chose to include this case study because it is agnostic of disability, but instead discusses a specific topic. For this case study, two researchers considered three sources. Two of those sources were videos and the third was a makeup line release. The makeup line release was "Rare" by Selena Gomez. Selena Gomez has rheumatoid arthritis. The makeup line features products with spherical lids that allow a user to push down instead of squeezing to open.

The first video was a product review by Molly Burke, a YouTuber and makeup enthusiast who is blind. Through Burke's video, we learned the importance of organization, scent, and embossing for her in any makeup palette. One researcher reflects on the impact of packaging in accessible design for makeups:

> Watching this video taught me to focus more on the small but impactful details on makeup products that affect one's ability to utilize it effectively

Burke calls out large makeup companies for not having inclusive design. We think more people with disabilities should be making design decisions in the beauty industry—just like Selena Gomez's new line.

The second video is on a morning routine for particularly anxious days made by Asia Jackson. Our main takeaway from this video was that jewelry and fashion can be used to ritualize self care. Putting on your favorite jewelry before beginning a process you may otherwise struggle with can make it more approachable and fun. Fashion can be used in many empowering ways, even if no one but yourself can see it. It is important that fashion is accessible in general and for the purposes of self-empowerment.

We should explore further how technology is already used and could be used for product recommendations by people with disabilities. People with different disabilities will likely have different product needs. For example, scent would be a barrier to people with chemical sensitivities, but Burke benefits from Too-Faced's food-scented products. Further, we would like to explore how these recommendations from people with disabilities could help companies do better.

8.4.4 Researcher Learning Survey

As we explored what could be learned from existing media with the undergraduate team, we discovered one of the primary contributions of the paper: Actively engaging with media made by people with disabilities can be an effective way for new researchers to learn about communities and working with disabled people. Each of the four undergraduate researchers had never previously conducted assistive technology research.

We anonymously surveyed the team after they participated in creating the case studies above. The survey consisted of both an adaptation of the Teach Access survey made by the Ability Project [453], and the Multidimensional Attitudes Scale Toward Persons With Disabilities (MAS) [454]. We also added questions on the perceived usefulness of the exercise. The only adaptation from the Teach Access survey was dropping the question on Web Content Accessibility Guidelines due to lack of relevance.

MAS delivers a vignette about a person (Joseph/Michelle) waiting with a friend of a friend who is a wheelchair user. The survey consists of 34 items rated on a 5-point Likert scale. The 34 items are categorized into three sub-domains: cognition, affect, and behavior. Users are asked to rate the likelihood that Joseph/Michelle experiences the 34 cognitions, affects, or behaviors. Scores are calculated by taking the average of all responses within the three sub domains, where scoring lower is better. The undergraduate team N(4) scored an average of 2.36 for cognition, 2.85 for affect, and 2.56 for behavior.

The Teach Access survey consists of 11 items (which we reduced to 10) rated on a 5 point Likert scale. The first eight items (reduced to seven) are self-reports of confidence in understanding of accessibility concepts. The last three are self-reports on interest in pursuing accessibility-related work. The average response to each question is illustrated in Table 8.1. It is no surprise that the team is highly interested in pursuing accessibility-related work (Q 8-10) as they self selected into this research project.

Q	On a scale of 1 to 5, how confident are you that you could do each of the following at this time?	Result
1	Give an example of a type of disability	5
2	Define Accessibility as a the term relates to technology and media	4.5
3	Give an example of inclusive or universal design	4
4	Give an example of how accessible technology is used by people with disabilities	4.5
5	Give an example of how assistive technology is used by people with disabilities	4.25
6	Give an example of a technological barrier somebody with a disability might face	4.25
7	Define the purpose of the Americans with Disabilities Act	2.75
8	Learning more about designing or developing technologies for and with people with disabilities	4.5
9	Pursuing a job or career in accessible technology	4.25
10	Pursuing research in the development of accessible technologies.	4.5

TABLE 8.1: Teach Access Survey

In addition to the measures above, we asked the team to report on if and how DREEM has changed their perspectives, whether it was a good use of time for the effort, what was most difficult about it, and what impact (if any) DREEMing had on their knowledge of disability best practices. Researchers report better understandings of potentially ableist actions:

> "As an abled person, I understand better the importance of including into any conversation instead of trying to speak for [disabled people]"

The team found value in their readings:

> "Instead of just doomscrolling or just scrolling in general, it gives me a focused reason to open social media and experiment with its algorithms to find communities I wouldn't normally find myself in. I feel that it's a good way to resist the algorithms that naturally filter us into niches."

And that there's still work to be done for access:

> "[DREEMing] taught me certain aspects of accessibility, especially in the beauty industry, are still not accessible to most people with disabilities"

All researchers report writing "thoughtful comments" being the most difficult part of the close reading process. As one researcher puts it "I kept on double thinking myself about whether or not I was properly empathizing with the subject's needs"

As a whole, one researcher thinks DREEMing helped them think more broadly about disabled people's experiences:

> "Rather than changing my attitude, DREEM helped to broaden my perspective and taught me to look beyond what is portrayed."

8.4.5 DREEMing as Design Thinking Pedagogy

The aforementioned post-survey with 4 undergraduate research assistants showed promise for using DREEM as an empathy-building educational tool. To explore this potential further, we worked with six high school students over an 8-week Summer Internship Program where students spent 10 hours per week DREEMing (they also spent 20 hours per week on other lab projects). For the first six weeks, students scraped content on TikTok from disabled creators, created new TikTok accounts, and trained the curation algorithm on the ”For You” page by following creators with disabilities and liking their content. Students logged daily reflection journals, logged content using the DREEM form, and inductively kept a log of themes to tag the data using a hashtag format. For the remaining two weeks, students applied design thinking to their leanings and created 21 low-fidelity paper prototypes for designs inspired by TikTok videos they watched. Students completed this exercise after being taught the importance of working directly with the target populations. Some interesting prototypes include an origami-style foldable ramp made of lightweight materials, a wearable device that provides navigation instructions using directional haptics, a device that provides alternate forms of communication at museums, an anti-sloshing smart cup that beeps when full, a legislation idea requiring cars to have specific lights dedicated to honking the horn, and a swimming headband that alerts us before bumping into the side of the pool. These prototypes can be found online[7]. Students reflected on how DREEM affected their perceptions of disability. Some of these quotes are included below:

> “I felt like I had a better understanding of“ableism” and how people with disabilities often do not wish to be treated in a way that signifies they need extensive help.”

> “I got to see how best practices stems from a multitude of criteria. Seeing examples of best practices through researching assisting people with disabilities definitely helped enhance this.”

When asked about whether DREEM was a good time investment:

[7] `https://tinyurl.com/HighSchoolerPrototypesDREEM`

> "Yes. I felt like I got to see the intersection between technology and disabilities. I also got the see how factors like the media and social norms affect such assistive tech. Devoting time to self-reflect also helped me to design prototypes that might be useful to people with disabilities."

When asked about the challenges of DREEMing:

> "At first, it was hard to analyze my own assumptions and biases of certain aspects of disabilities objectively. During self-reflection, I had to spend more time on that and challenge myself to view the daily lives of people with disabilities in different ways."

As mentors, we saw marked improvement in student knowledge and empathy towards populations of people with disabilities. Each student seemed to gravitate towards a particular community they were interested in learning more about and building partnerships with. I am excited about the potential of embedding DREEMing in schools to incorporate social justice perspectives in the classroom for the next generation of engineers, policy makers, and citizens. I see DREEM as fertile ground for new pedagogical approaches to teaching disability justice.

8.5 DREEM

In this section, I introduce the four resulting steps to DREEMing. The process of completing this methodological framework is inspired by the influences discussed in the previous sections. Each of the four steps are discussed in detail with tips and insights derived from employing the method in the case studies described in the following section (Section 8.4). The nature of DREEMing is qualitative and, therefore, a quantitative evaluation of the method is not appropriate (at least until more case studies adopt the method, when a systematic analysis can be conducted). Instead, we illustrate the value of DREEMing through the contributions of three case studies and through the reflections [455] in our Discussion (Section 8.6). Steps 1-3 can be repeated for as long as necessary until data saturation is reached. For data saturation, we recommend using a diverse range of platforms and media, and finding numerous subgroups within the target community. It is possible that steps 1-3 will need to be revisited and repeated based on later research phases.

After reflecting on our case studies and survey of the researchers, in addition to our original three steps of the DREEM process, we have added a Step 4 (Generation of Research Agenda). This step allows the researcher to reflect on their findings and refine them into a potential path forward for the research.

Below we offer a detailed explanation of each step of DREEM along with our insights based on our experiences employing a version of the method. In each step, we pose some "tips for success" that we generated after our own stumbles in using and training in DREEMing. We conclude this section with suggestions for presenting the findings from DREEM and our reflections on DREEMing as a team.

8.5.1 Step 1: Discovering Relevant Media

Any public medium has potential for DREEMing including blogs, images, videos, films, tweets, and posts. So far, we have primarily considered videos and text-based pieces in our case studies. Media such as visual art are certainly possible, but require further exploration and a grounding in visual studies. We focus on media that can be found online for ease of access. There does, of course, exist important media made by people with disabilities that cannot be found online. It is possible to close read in-person performances, but having a recorded version offers the ability to sit with and return to the content. Zines and event ephemera could also offer interesting insights. This method could reasonably be extended to any of the above (and more!).

8.5.1.1 Tips for Success

Finding media created by people with disabilities online can be a surprisingly difficult task. For example, when looking for content from creators with autism, searching for "autistic" might seem like a good place to start. Unfortunately, it will likely result in informational content such as the biology of a disability rather than the lived experience or perspectives from a non-disabled creator. Furthermore, finding such media may require some prior community knowledge (hashtags, vocabulary, etc.) that may be difficult to access for an outsider. We found that trying to find ways "in" to a community via hashtags or through snowball methods were the easiest way to find appropriate content. We offer the following tips for success in finding content creators with disabilities online. Examples of each are listed with each tip.

- Search common content with flavor: 'what's in my bag: chronic illness edition', 'amputee morning routine'
- Learn community hashtags and keywords, which vary from platform to platform: #ActuallyAutistic, #Spoonie, #CripTheVote, #ADHDTwitter
- Train the curation algorithm: Create a new social media account and follow only creators with hearing impairments as you find them.
- Snowball: Discover accounts that a creator you follow tags.
- Look for collectives and anthologies: SinsInvalid, Disability Visibility Project

8.5.1.2 Important Considerations

There are several pitfalls to finding media on the web. We encourage DREEMers to carefully consider whether certain media sources need to be taken with a grain of salt, supplemented, or left out all together. First, consider whether the media source perpetuates ableism and how. If you do not feel confident in detecting ableism, or could use a primer, you might first consider seeking out media made by disabled people on how ableism appears. A good place to start might be with some of the videos discussed in Section 8.4.1. Second, media is not all-telling. It is made by individuals or small groups, and may not represent the community as a whole. It is important to explore different perspectives from creators with disabilities. Third, anything that has been shared exclusively with a private network should probably be kept that way (See Section 8.3.1). Fourth, different social media platforms have different affordances and cultures. A TikTok video may be curated for a specific "in-crowd" audience because of the nature of community building inside the platform, while a YouTube video might be for a broader audience because of its longer form and reach. Last, relatedly, consider who the target audience is for the source. It is highly possible that the media wasn't made for outsiders to the community and uses terminology or makes light of certain subjects that would not be appropriate for an outsider.

8.5.2 Step 2: Close Reading

This step requires reading or observing the media, and sitting thoughtfully with it as described in Section 8.2.3.1. We recommend working systematically and using standardized collection measures. We include an editable Google form for DREEMing in the supplemental materials online[8]. Relevant details to log beyond the close reading itself include the source of the media, a short 1-5 word summary

[8] `https://tinyurl.com/DREEMForm`

that makes skimming the data later easier, annotated screenshot(s), location in the media the close reading entry relates to (e.g., line number, time span in video), and keywords/tags. We enter each "complete thought" as one unit—these could be a few words or a few sentences. We also logged questions we asked ourselves that arose during the close readings. You can choose to immediately start logging your visceral reactions or start entering close readings after you've been fully exposed to the media, but we recommend doing both.

8.5.2.1 Tips for Success

Record your thoughts as they occur. These may directly relate to the content in the video or may be personal to your lived experiences. As you go, maintain a list of keywords and tag each recorded thought. These keywords can make indexing easier later. Our team took advantage of google forms and spreadsheets for this step. In general, take your time through this step. It may be useful to step away from the media and come back. Multiple reads may lead you in different directions.

8.5.3 Step 3: Reflection and Empathy Building

Reflection is a crucial part of DREEMing. The primary aim of DREEM is to learn about communities in an authentic and lasting manner. Reflection creates the time and space to absorb your learnings and connect them with one another. Reflection is an important part of making sustainable perspective change [456]. We recommend doing a session of reflective journaling after each analyzed media artifact. Maintaining a paper trail of your evolving thoughts also allows you to incorporate the learning process itself into the content analyzed via inductive thematic coding.

8.5.3.1 Tips for Success

We like using the following prompts for our reflections. You do not need to make each reflection similar in structure to one another, and can choose or combine prompts as they seem relevant.

- What trends or patterns do you see emerging?
- Have you learned anything new about the community you are studying?
- What could you improve about your logging process?
- What is valuable or not valuable to you as an individual about your process?
- If working with others, what are similarities and differences you are seeing in your logging or retrospective writings versus your peers?
- Have you learned anything that could inspire technology design?
- What questions will you explore next and why?

We often would quickly answer all of these questions in one diary-style entry or go in-depth with just one of them. We kept these prompts at the top of our diary documents to inspire us.

8.5.4 Step 4: Generation of Research Agenda

The goal of DREEMing is to provide a pathway into being an advocate for a more inclusive and accessible society through partnerships with communities of people with disabilities. There is much work to be done and it can be overwhelming—it is important to plan and focus on a specific idea or subset of the field or else it will seem unmanageable. At some point you'll reach saturation from completing steps 1-3 iteratively and hopefully have some ideas. It is also important to prepare for the inevitable evolution of research and the new ideas that will naturally emerge. From here, a researcher can take their research agenda to participatory design workshops, action research in relevant communities, or any other number of potential research avenues.

8.5.4.1 Tips for Success

Developing research agendas and research questions is an art in itself. We recommend writing the research paper you hope to publish prior to collecting any data or doing any design work—the process will inform the questions you ask and *how* you ask them. When forming research questions it may be helpful to apply the SMART (Specific, measurable, attainable, reasonable, timely) model strategically [457]. Ask yourself:

- Is this agenda true to the authentic experience of the community?
- Am I the right person to approach this work?
- Is the scope possible to tackle?
- Should technology be used in relation to this experience, or would a different intervention be more appropriate?
- Does the agenda uplift and support the community at all stages?

While there are many compelling software-based annotation tools and qualitative visualizations used by scholars in Digital Humanities [458], we found no easy way to experience our dense reflections at a higher level. While constructing our case studies, we struggled with how to present DREEM findings for higher-level reflections, so we decided to create a website that was highly effective in assisting with our analysis, shown in Figure 8.1. The website allows researchers to import data

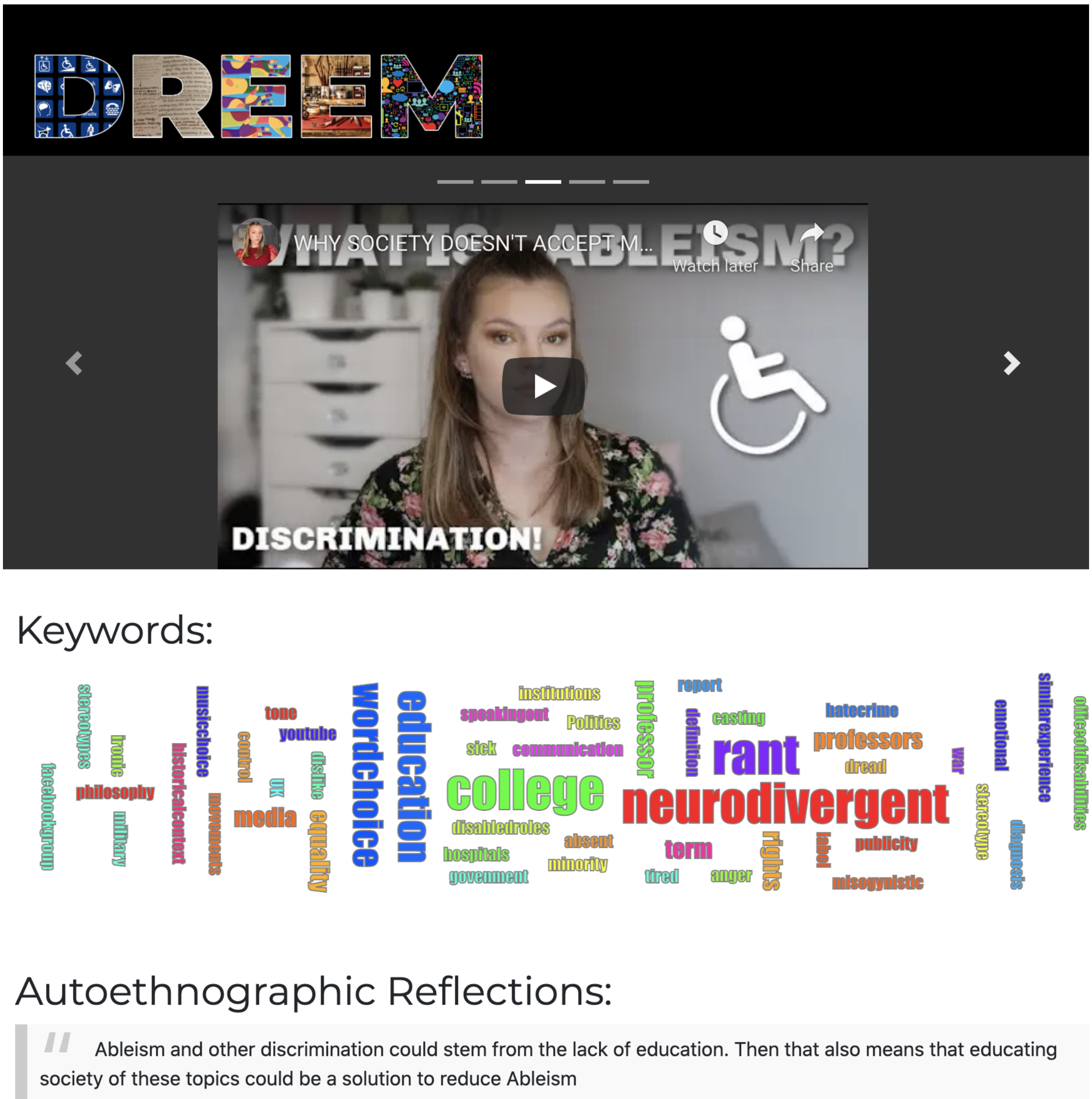


FIGURE 8.1: A screenshot of the DREEM review tool. Users can upload their close readings to analyze what they've collected all in one place. The review tool uses a carousel to flip through the various media sources quickly and see relevant close readings below, sorted by time or location. Under the carousel is a word cloud of the keywords to visualize the qualitative themes. There is a specific area for direct quotes that highlight the reflections

from the DREEM Google Form related to a particular topic. The website dynamically loads media sources including *TikToks*, *YouTube* videos, website previews, and podcasts into a carousel that the researcher can flip through. The table at the bottom of the page only shows close readings that correspond to the active media source in the carousel. A word-cloud of keywords is automatically generated and the reflective journal entries are highlighted in block quotes. The current version of the tool is available online[9].

8.5.5 How to Present DREEM Findings

DREEM findings can be presented as their own findings, or as a step within a larger body of work. In each case, the presentation of the work will look slightly different. This method generates research questions, so it is likely that the findings will become a part of the larger body. In the case that DREEM is presented as the primary finding, the outcome may look similar to a traditional close reading that focuses on a particular topic and discusses multiple sources. [459] and [460] are two good, and very different, examples of close readings.

We encourage researchers to share important elements that are specific to the DREEM process such as links to all media analyzed (regardless of if it is discussed in the body of text), keywords and their frequency, and a thematic analysis of the individual close readings and/or reflections.

8.5.6 DREEMing as a Team

DREEMing can be done on your own or as a team. If you plan to work as a team, we offer some insights based on our experiences. We found that DREEMing has the potential to be an effective way for undergraduate research assistants and

[9] `https://tinyurl.com/DREEMReviewTool`

assistive technology newcomers to become acquainted with people with disabilities. DREEMing as a team offers the ability to discuss and build on each other's work. As has been discussed in other literature, teaching accessibility concepts to undergraduates continues to be a challenge [418]. We offer this as one framework for learning towards that goal.

It is not required for multiple team members to do close readings of the same media. However, doing so can offer insights from multiple perspectives. We found that comparing each other's notes led to fruitful conversations about the researcher's individual experiences and insights that might have been missed if everyone was working independently. We recommend leaving time in your research process to read each other's close readings and journals and meet to discuss them. Teams should work together to find a logging process that works for everyone. Expectations for quality and length of passages should be set and continually talked about.

8.6 Final Thoughts and Conclusion

To conclude, I will leave the reader with some final thoughts on the opportunities and challenges presented with DREEM, future directions, and summary of this work.

8.6.1 Opportunities

DREEM has become increasingly relevant in the wake of COVID-19. It can be challenging to include people with disabilities for participatory and community-based work generally [273], but there is a specific added risk during a global pandemic. In addition to general guidelines that limit in-person contact, populations of people with disabilities often have medical needs that place them at higher risk from the COVID-19 virus [241]. In light of quarantine, designers are employing creative methodologies to carry out remote design work that is usually done in situ [240] (e.g., using games to educate the public about COVID-19 and collect data [275]). Many of these technologies are not accessible to people with disabilities [239]. DREEM allows researchers to safely conduct preliminary research in preparation for participatory work when in-person protocols are safe after ubiquitous vaccination.

DREEM surfaces and features existing work and labor of disabled people. The validity of research can be more rigorous if the source of inspiration is surfaced and credit is given where it is due. DREEM extends participatory design and community-based research from being inclusive on *how* something should be made to *what* should be made in the first place.

8.6.2 Challenges & Limitations

This method requires access to content created and posted online. Content creators with particular disabilities are relatively few on some mediums due to accessibility issues. Memes and GIFs for instance are often posted without alt text [461], so the participation of screen reader users with memes and GIFs may be lower. Related, different social media platforms have their own affordances and norms as discussed in the previous section. Therefore, investigating multiple platforms will help increase the diversity of the findings using DREEM.

Researchers must be careful not to over generalize as not every disabled individual will be represented by those who are creating content online (i.e., a disabled individual who does not have access to creating certain media or has no desire to create content on social media may have a very different experience than someone who does have access and a desire to create and post content.)

Finally, the challenge of training individuals to recognize and flag ableism and ableist content is ongoing. We have tried to mitigate this with our trainings and suggestions in this paper, but recognize this is a thorny issue that will need continual appraisal.

8.6.3 Future Work

In this chapter, I presented several case studies that demonstrate DREEM. However, the research agenda created by the findings of each case study have yet to be enacted. Application of this method to longer-term projects is needed. The research team intends to follow up on the case studies presented here as their own research projects. We chose to conduct the survey in Section 8.4.4 as our findings developed because we saw the change in the undergraduate researchers' language and comfort around topics of disability. In the future, it would be worthwhile to conduct the survey twice as both a pre and post survey. Our work with DREEM has primarily considered videos and text passages. More work should be done to DREEM with visual art and audio. We are excited to see what others come up with when using DREEM.

8.6.4 Conclusion

In this chapter, I propose DREEM, a 4-step nascent method for using close readings of media posted by people with disabilities to build empathy and authentic research agendas prior to participatory work. The primary contributions include materials for utilizing DREEM, including trainings, data logging templates, and a tool for visualizing close readings. I found that actively engaging with media made by people with disabilities is an opportunity for new researchers to learn about these communities and working with disabled people. The potential benefits of continuing this line of work include shared labor, authentic research problems, increased visibility of disability communities, and healthier partnerships with communities of people with disabilities.

8.7 My Role

Founders of DREEM include Leya Breanna Baltaxe-Admony, Kathryn Ringland, and myself. We lead a team of undergraduate researchers who collaborated on the case studies, including Ryoma, Ellen, Eric, Quinn, and Rafael. I helped formalize DREEM, created the initial DREEM tool implementation, led the creation of training materials, and contributed a small amount of close readings.

Chapter 9

Chasing Play and DREEMing on TikTok

9.1 Introduction

In this chapter, I share experiences employing both SPD and DREEMing to illustrate their utility and value through an exploration of scraping content on TikTok from creators with disabilities. This chapter aims to show the potential of combining these methods. Two mainstream ways by which technology can be designed to accommodate users with disabilities include creating technology that provides a specific service to people with disabilities (Assistive Technology) and making general technology more accessible to people with disabilities (Accessible Technology) [462]. It is very pragmatic and vital to include people with disabilities in the design process in both cases. This chapter is motivated by the need to include populations with disabilities to inspire design more broadly and generally, looking at values other than efficiency and accessibility. We design better technology for everyone when we include people with disabilities early and often in the process [463].

I am particularly interested in designing technology that supports play. Play for its own sake is valuable [30]. Play and playfulness can have a positive impact on the well-being of individuals and groups [84, 337]. Play provides us with the agency to be creative, express ourselves, and learn [16, 338]. Play creates opportunities for meaningful social connection [83]. Play is universal to all humans (and possibly all living creatures) [30], including humans with disabilities. People with disabilities are playful (e.g. [98]) and how they play [464] can benefit the design of technology and improve society at large. Playful technology designed with people with disabilities has the potential to educate the general population about people with disabilities, increase the visibility of people with disabilities, and support social relationships between people, regardless of their disability status.

It can be challenging to include people with disabilities in participatory work generally [273], but there is a specific added risk during a global pandemic. In addition to general guidelines that limit in-person contact, populations of people with disabilities often have medical needs that place them at higher risk from the COVID-19 virus [241]. In light of quarantine, designers are employing creative methodologies to carry out remote design work that is usually done in situ [240] (e.g., using games to educate the public about COVID-19 and collect data [275]). Many of these technologies are not accessible to people with disabilities [239]. Co-Design sessions should be valuable to all parties [274], but they disrupt everyday life and require participants to invest their precious time. I am interested in tapping into the tacit and contextual design knowledge of people with disabilities on platforms they are already using to share content for all of these reasons. Social media is rife with potential design material. I chose to focus on TikTok because it is an inherently playful social media platform and it is a safe way to engage with populations of people with disabilities during a pandemic in a way that is not disruptive to their everyday life. To capture play potentials [333] on TikTok, I employed the Situated Play Design methodology [332]. These play potentials inspired design concepts that could inspire future technology.

In this chapter, I present a catalog of design concepts to inspire future playful technology based on play potentials from people with disabilities. To arrive at these design concepts, we chased play potentials on TikTok by scraping videos from content creators with disabilities. We analyzed the scraped content and present seven emerging themes that helped inspire and generate the design concepts. Finally, I discuss the relevance of the seven emerging themes and our design concepts' possible implications.

9.2 Background

In technology design, people with disabilities are usually included to make general technology more accessible or make a technology solution to address a specific need for a population of people with disabilities, which is discussed in the first section. Next, I discuss some examples of playful technologies designed with and for people with disabilities to achieve utilitarian goals. I then discuss standard methods of how these populations are usually included in the design process, but how play is not usually the goal, whereas play is this work's goal. Finally, I discuss how combining SPD and DREEMing is appropriate for designing technology inspired by how people with disabilities play.

9.2.1 *Accessible* and *Assistive* Technology

Accessible technology can be used by all people in the target audience regardless of disability status [463]. Technology that is not accessible places a handicap [465] on people who do not have equitable access to the services that technology is designed to provide [11]. A handicap is not a person's disability—it is the barriers that society and technology place on people with disabilities [11]. Too often, making technology accessible is an act of retrofitting solutions to make the original tech usable by people with disabilities [466], when these populations should have been included in the first place, resulting in designs that are more accessible and user-friendly for everyone [463]. *Assistive* technology is meant to serve a specific need of a population of people with disabilities and is meant to be used primarily by people with disabilities, caretakers, and medical professionals [467]. Assistive technology should be accessible to the target population so that they can use it—and common co-occurring disabilities should also be considered [468]. Technology design that includes people with disabilities often naturally becomes playful or includes elements of play, which results in novel and interesting user experiences (e.g. [94–97]). In these cases, play emerged naturally, but may not have been sought out directly. This work is interested in designing technology that is directly inspired by play.

9.2.2 Playful Technologies and People with Disabilities

As is true for people in general, people with disabilities are playful [98]. Play and games can serve people with disabilities in numerous ways, including increasing their visibility, improving public perception of people with disabilities, and fostering healthy connections in communities. Public visibility of people with disabilities and designing for social acceptance can reduce stigmas [99]. Negative socio-cultural stigma continues to dissuade people from using their assistive technology [100], leading to isolation and worry about unwanted attention [101–104]. Oppression of people with disabilities is systematic, political, and sociocultural [4]. Historically, people with disabilities have put in the labor to improve their rights (e.g., the disability rights movement [4]), but all of society should actively participate in the shared responsibility. Play has the potential to make some of this labor feel less like work. In this work, we aim to create playful design concepts inspired by people with disabilities and speculate [19] about a future where these technologies can playfully support societal growth and opportunities for the inclusion of people with disabilities.

9.2.3 Designing Assistive and Accessible Technology

By their nature, several design methods are potentially supportive of the participation of people with disabilities for creating assistive and accessible technology [181]. Participatory Design [166] encompasses a variety of methodologies that can productively and effectively include people with disabilities as co-designers including focus groups [469], wizard of oz [233], cultural probes [470], brainstorming [471], and bodystorming [328], to name a few. To successfully implement these design methods, it helps to take an ability-focused approach [462]. When people with disabilities are included early and often in the design process, the resulting design artifact is often universally accessible and more usable by everyone [463]. In both participatory design and universal design, the inclusion of people with disabilities is not meant to benefit only a minority of the population, but rather everyone who engages with the design [463]. Playful technology inspired by people with disabilities has the potential to be universally beneficial for anyone interested in engaging. Many of our design concepts, described later, are potentially exciting to people regardless of their disability status.

9.3 Research Method

Situated Play Design and DREEM are apt methodologies for our work because they allow us to unearth playful behaviors from people with disabilities. These behaviors can be shared with fellow designers to inspire future technology and contribute to future designs, either those to support play wholly or those with other purposes where incorporating playful aspects could be beneficial. Situated Play

Design is an extension to existing play design approaches that focuses on uncovering existing manifestations of contextual play as a starting point for designing for situated and emergent playful engagement [333]. Due to the safety concerns related to COVID-19 and the higher health risk status of many people with disabilities, we employed a contact-free approach to the SPD and DREEM methodologies. SPD is an open methodological framework flexible enough to complete all three steps of chasing *play potentials* despite the constraints of conducting research during the COVID-19 pandemic. For the first step, we chased play potentials and their contextual manifestations by scraping existing content from content creators on TikTok with disabilities using a *Netnography-style* approach [440], which we describe in depth in *Scraping Content* below. For the second step, we took a generative approach to develop a catalog of design concepts that could inspire future playful technology artifacts inspired by the *play potentials* we scraped, described in depth in *Designing Concepts* below. For step 3, we formed intermediate-level knowledge via our seven emerging themes and we envisioned the impact of our designs in the *Discussion* by imagining speculative futures [19]. This work provides an opportunity for "design after design" [381] when we are not constrained by current technical limitations and after the pandemic when it is safer to engage with populations with disabilities. The specific research questions that drove this work are:

RQ1: *What play potentials exist from scraping content on TikTok from creators with disabilities?*

RQ2: *What themes emerge from DREEMing on scraped play potentials, and how does the TikTok platform influence the results?*

RQ3: *What kinds of designs can the scraped play potentials inspire, and how might these designs affect society?*

Due to the COVID-19 pandemic, we wanted to safely and non-intrusively chase play potentials from these populations as part of our broader research agenda [332], which is why we chose to scrape existing content on social media. We chose TikTok because: (1) it hosts massive amounts of playful content, (2) the video format affords capturing interactions and often more context than images, (3) people with disabilities have already adopted the platform, and (4) features of the app allow us to find relevant content, such as the keyword search and the "For You" page described below.

I mentored five high school students over an 8-week summer internship through a program called Science Internship Program. The students worked on various computational media projects related to designing and creating technology for people with disabilities, including this project. The five high school interns did the majority of the content scraping, data analysis, and design concept sketching, under our guidance. All high school interns completed the required training for conducting ethical research on human subjects, received the training certificate, and are officially in our research protocol approved by our institutional review board. All high school interns watched recorded lectures from undergraduate classes that researchers taught to conduct a qualitative/thematic analysis. All interns worked full-time with researchers and were highly supervised, including daily meetings and regular auditing of their work. All interns were exceptionally brilliant high-performing students in the top 10% of their high schools—and all were members of historically disadvantaged communities and minorities. Classically trained HCI Researchers were responsible for overseeing the high school interns, aggregating the coded data, computing the agreement, and presenting the results.

9.3.1 Scraping Content

TikTok logs videos that users interact with and the creators that people follow to train an algorithm that curates custom suggestions hosted on the main page, the "For You" page. Each student created a new TikTok account so that the curation algorithm would start with a clean slate. For the first week, the interns spent an hour a day liking videos that they thought featured an interaction or behavior that could lead to a play potential (liberally defined). By doing that, they trained the algorithm to highlight playful content on the "For You" page. For the second week, the students started to train the algorithm to curate playful content from creators with disabilities by following creators with disabilities and favoriting playful videos featuring people with disabilities. To seed the algorithm, the high school students searched for relevant hashtags such as #disability, #disabled, #blind, #deaf, #signLanguage, #cerebralPalsy, #accessibility, #colorBlind, #impairment, #handicap, #autism, #ASD, #play, #game, #fun, and #haha. The keywords included general terms related to disability, specific disabilities, and terms to influence the algorithm to show playful content, similar to the strategy discussed in Chapter 8. Videos that contained play potentials were logged into a Google Sheet (provided in the supplementary materials) that contains a link to the video, the content creator's handle, a brief description of the video, and space for the students to list keywords and themes (RQ1). To ensure the integrity of access to the content for data analysis, we also stored all logged videos and a link to the copy, which was prudent because of the potential bans to TikTok that took place after we started. We asked interns to complete daily reflections, as described in the DREEM chapter (Chapter 8), to reflect on the experience and process of scraping content on TikTok from users with disabilities. By the third week, the "For You" page was populated with relevant videos from people with disabilities containing play potentials. When the content was stale, the interns seeded the algorithm with more relevant hashtags and logged relevant videos from their searches. The research team met weekly to update the hashtags bank and discuss tactics for seeding the algorithm to continue curating relevant content. The interns scraped content for an hour a day, five days a week, for four weeks (inclusive of the time it takes to log videos in the spreadsheet).

9.3.2 Data Analysis

Students independently generated a list of themes for the videos and then collaborated as a group to propose a set of combined themes to the research mentors (RQ2). Research mentors created the final theme names to be concise and descriptive during a group meeting. The seven themes are non-exclusive and are discussed in detail in the Emerging Themes section. Interns spent an hour a day for a week analyzing the logs and tagging relevant themes. We hypothesized that TikTok is a very performative platform with a few instances of introspective reflection. To better understand how the platform impacted our results (RQ2), interns placed each play potential on a spectrum of introspective to performative. Interns highlighted exemplars (their favorite play potentials) and listed technology mediums that might be relevant such as mobile devices, the internet of things, and wearables. The completed analysis is included in the supplementary materials. We highlighted exemplars because we wanted to design technology directly inspired by exciting play potentials in context. We added possibly relevant technology mediums to inspire ourselves to think about diverse application possibilities.

9.3.3 Designing Concepts

For week 6 of the internship, I asked interns to brainstorm one concept individually for each theme. I had them work individually to assess each student's individual strengths. In week 7, students worked in pairs to brainstorm more ideas and present them to the larger group. Without any prior design experience, I challenged students to ignore the current limitations of technology, to design around playful moments instead of entire systems, to be specific, to present their ideas visually, and to think beyond "helping" people with disabilities. I gave these directions because speculative design [19] plays creatively with current technology limitations to imagine futuristic-yet-plausible designs in ways that transgress existing design directions. I then facilitated a group brainstorming session where we watched TikTok videos marked as exemplars selected by students and then let students pick resulting design ideas to create sketches. In week 8, I provided feedback and tools on improving their design concept sketches used in the interns' final presentation for the program. I then did one final iteration on the interns' designs presented in the Design Concept Catalog section of this chapter (RQ3). I reflect on these design concepts' possible implications in the "Discussion" section of this chapter (RQ3).

9.3.4 Ethics

The high school interns participating in the Science Internship Program at University of California Santa Cruz are minors. Interns' parents or legal guardians signed consent forms to allow them to participate in summer research projects, including the work presented here. In addition, all high school summer interns completed the required training for conducting ethical research on human subjects provided by University of California Santa Cruz, received the training certificate, and are officially listed in our research protocol approved by our institutional review board.

This research was reviewed and approved by our institutional ethics review board. A tricky element of our research is scraping existing content on social media and the ethical implications of researching on these platforms. Our data collection method closely aligns with *Netnography*[440], which has established ethical guidelines [449].

These include the notion of public versus private information on social media, whether to anonymize or cite participants, and informed consent. Kozinets argues that ethical procedures must be decided on a case-by-case basis contingent upon the topic matter, the research purposes and the research approach of the particular *netnography* [440]. Some platforms such as Facebook and Instagram have varying levels of security and privacy settings for content and profiles that complicate what is truly public. Researchers using platforms with privacy settings must respect what is considered public and not. TikTok is designed to be entirely public-facing. TikTok is not designed to group people, create small social circles, or share private information to subsets of people—instead, it is an open broadcasting platform where content creators try to reach as many people as possible, strangers or otherwise. Bassett and Kozinets argue that when the internet is used as a "megaphone-like" public broadcasting medium [450], we can thus perceive it as a form of cultural production, in a similar framework to that of the print media, broadcast television and radio where we should cite the source so that broadcasters can be credited for their work [449, 451]. Because this research is minimal risk and fits the notion of public broadcasting online, we provided links to the original content in our published materials to respect the creators' (ongoing) decisions concerning public access to the videos. *Netnography* of public archival content (not active research interventions such as interviewing) like the scraping methodology employed in this research would be unduly complicated with informed consent because the manual, non-automated access by researchers of public information should be acceptable without special permissions or actions [452] and removing information from unreachable broadcasters would undermine researchers' ability to contribute to society [449]. Therefore, we included all applicable data scraped in our supplementary materials and make every effort to represent the content in this publication respectfully and in a positive light. Finally, our data was manually scraped without any automated system or software and is not used for commercial purposes, and therefore, at the time of writing, adheres to TikTok's terms of services.

9.4 Emerging Themes

Five high school students individually analyzed their subset of videos to categorize them into the seven emerging themes. Each theme is discussed in detail in the following sections. There were 285 unique videos total and 24 videos analyzed by two or more students, causing an overlap (RQ1). The theme categories are nominal, non-mutually exclusive, and there were five total raters. Between all seven themes in the 24 overlapping videos, two or more raters agreed on whether or not a video belonged to a theme 147 times and disagreed 27 times, resulting in an average agreement of 84.48%. While scraping content, interns marked exemplar videos that showcased play potentials they felt could directly inspire technology design. The number of videos in each theme and the number of exemplars marked for each theme are shown in Table 9.1.

TABLE 9.1: Distribution of TikTok videos by theme

Theme	Total	Exemplars
Everyday Theatrical Life Sketches	130	11
Playful Advocacy	110	7
Debunking Myths/Stereotypes	24	7
Gamification Therapy/Rehab	51	25
Impossible Challenges	12	7
Perks of my Disability	10	1
Duet Differences	12	3

Some people with disabilities use TikTok to log their personal reflections, while some use it to reach an audience—the distinction is whether the video was originally recorded for oneself or others. I hypothesized that the performative nature of TikTok and the completely public-facing broadcast affordances of the app would lead to videos that trend outwards from self (away from introspective and reflective content). Therefore, raters placed each video on a 5-point Likert scale where 1 is

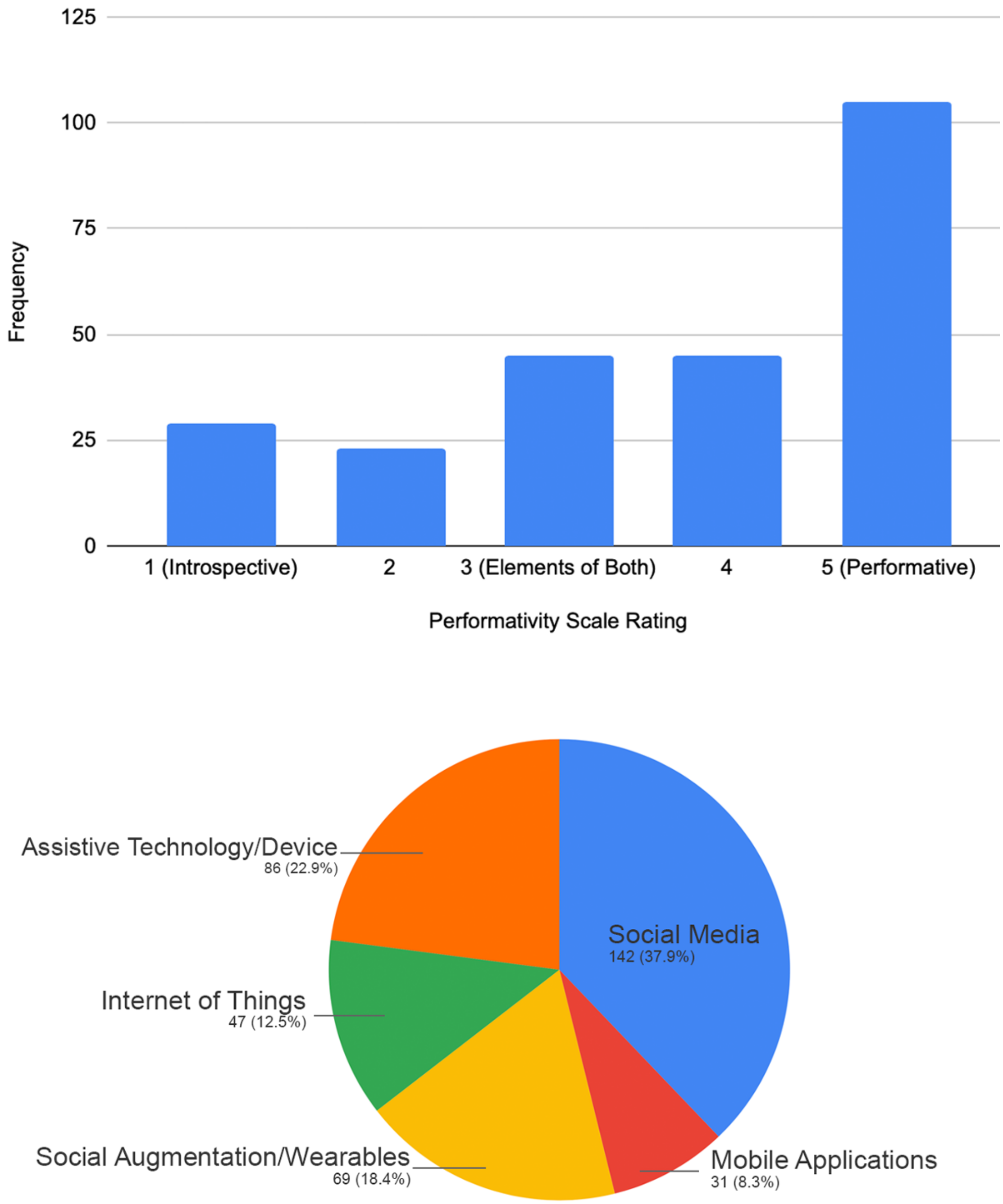


FIGURE 9.1: On the top: Frequencies of TikTok videos rated on a 1-5 *performativity* Likert scale and on the bottom: a pie chart depicting the frequencies of which mediums each video inspired. There were 29 videos that were rated as totally introspective, 23 were given a rating of 2, 45 had elements of both, 45 were given a rating of 4, and 105 were totally performative. There were 86 play potentials that could inspire Assistive Technology/Devices, 47 that could inspire IoT designs, 69 that could inspire Social Augmentation/Wearables, 31 that could inspire mobile applications, and 142 that could inspire Social Media Design.

totally introspective (like a diary entry), 3 has elements of both introspection and performativity, and 5 is totally performative (like a talent show). The resulting mean is 3.7 with a standard deviation of 1.38, and a skew of -0.72, confirming my hypothesis that content on TikTok is generally more outward-facing. As shown in the top chart of Figure 9.1, the frequency of the rating is highly skewed towards performative, where points were averaged and rounded when multiple raters analyzed the same video. These results conclude that the TikTok platform does impact the type of play potentials that can be scraped from the platform (RQ2) and, therefore, the types of designs we can expect it to inspire. Interns were also asked to imagine what technology medium might be most interesting to design for, given the play potentials in each of the videos. The frequency of each medium is displayed in the pie chart in the bottom of Figure 9.1.

9.4.1 Everyday Theatrical Life Sketches

Videos that showcased dramatic performances of "A day in the life of a person with a disability" were categorized into the *Everyday Theatrical Life Sketches* theme. Of all the seven themes, this is the broadest, and many of the videos sorted into this theme are also sorted into many of the themes described below. Within this theme, we saw many types of dramatic performances that featured humor, skits, and reenactments. We saw many similarities between the strategies content creators used and the improv methodologies used by actors [472]. In particular, content creators would try to recreate moments that were not initially captured on camera but would enhance or dramatize it to be more appealing for their audience. These moments they tried to recreate did not always go as planned, and sometimes the bloopers created more exciting posts, much like an actor might do during an improv sketch.

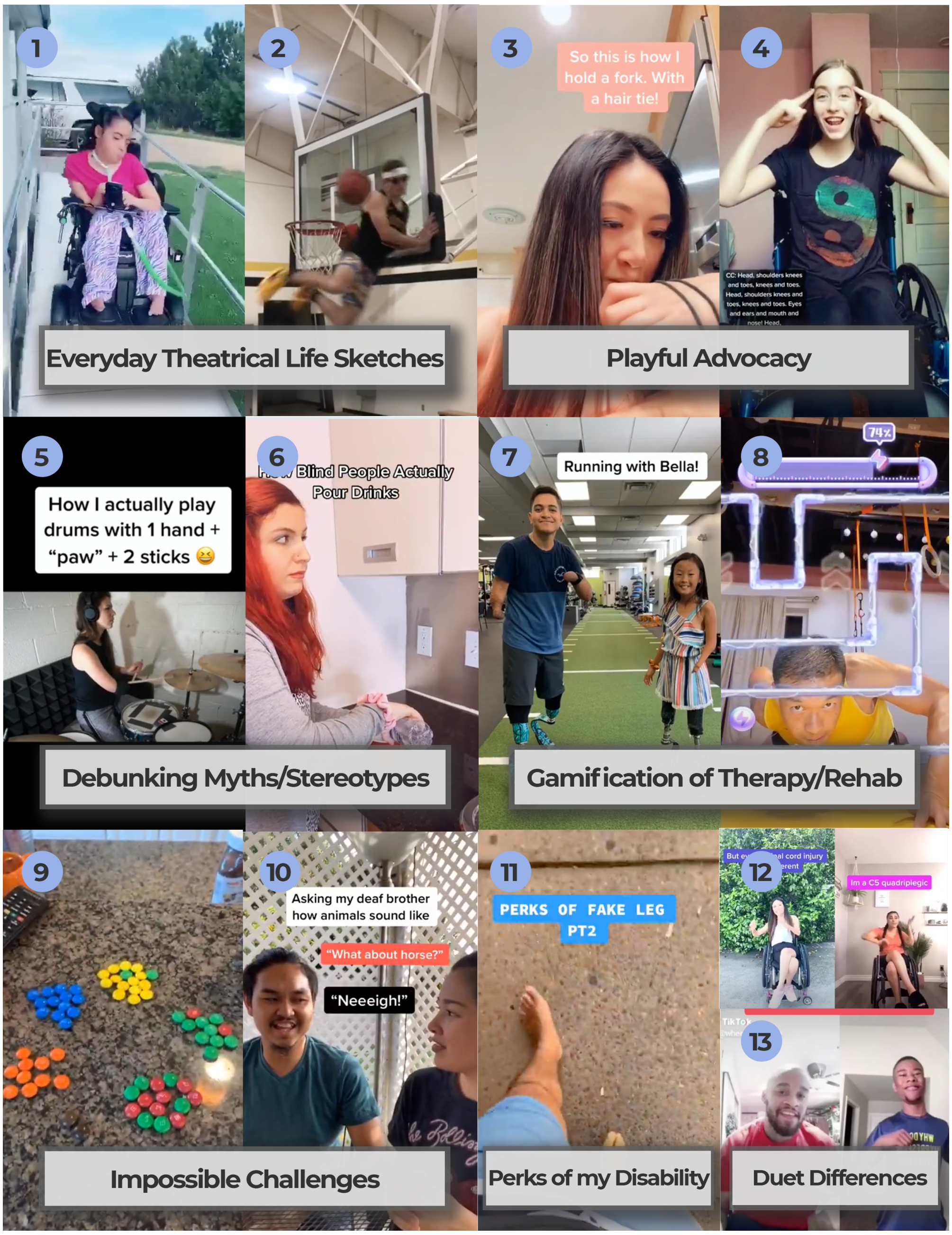


FIGURE 9.2: Example TikTok videos organized into each theme labeled by number and described in the text

In Figure 9.2, the TikTok screenshot numbered 1 depicts a person confidently navigating their house backward in a wheelchair without looking[1]. The TikTok screenshot numbered 2 in Figure 9.2 shows a blind person humorously crashing into a basketball board[2]. These examples' juxtaposition is interesting because they depict dramatic reenacted moments that represent extreme levels of ability. The first shows mastery of assistive technology that removes a handicap while the second shows how sight is required to play basketball. In both, the background music was carefully selected—in the first, it creates a confident effect, and in the second, it climaxes to a moment of surprise and humor.

9.4.2 Playful Advocacy

Videos that educate the general population on disability subjects were categorized into the *Playful Advocacy* theme. The effect of these TikToks was generally light-hearted and creative. For example, many videos described proper social etiquette related to disability that creators prefer, such as avoiding pulling blind people by the hand or tugging at their sleeves when helping them cross the street (Instead, offer your assistance, and they will tell you the best way to guide them).

In Figure 9.2, the TikTok screenshot numbered 3 shows a person who has quadriplegia explaining how they use a hair tie to hold a fork[3]. The TikTok screenshot numbered 4 in Figure 9.2 is of a person in a wheelchair singing about their partial paralysis[4]. The creators set up a positive and welcoming environment by smiling and using upbeat sound effects in both posts.

[1] https://tinyurl.com/y3jj8jeu
[2] https://tinyurl.com/y6yvkecs
[3] https://tinyurl.com/y4c66299
[4] https://tinyurl.com/y4jt5gfo

9.4.3 Debunking Myths and Stereotypes

Posts that bring to common light misconceptions of people with disabilities are categorized into the *Debunking Myths and Stereotypes* theme. These videos are often formatted by illustrating the difference between how the audience thinks people with disabilities complete certain tasks versus how they actually complete tasks. Many feature solutions on how people with different disabilities complete everyday tasks that people without disabilities often would not consider, such as the affordances of different types of wheelchairs. Content in these videos is sometimes exaggerated to make a stronger point—16.12% are also categorized as *Everyday Theatrical Life Sketches*—but most are more serious, and many are responses prompted by disrespectful comments on the platform from trolls.

In Figure 9.2, the TikTok screenshot numbered 5 shows a drummer with 1 hand using 2 drumsticks[5]. The TikTok screenshot numbered 6 in Figure 9.2 is a blind person showing the difference between how their audience thinks they pour a glass of water versus how they actually pour it[6]. Both are in response to a misconception that their disability prohibits them from possessing a skill or needing help to complete tasks.

9.4.4 Gamification of Therapy/Rehabilitation

TikTok videos that feature games, competition and challenges that motivate completing exercises related to one's disability are categorized into the *Gamification of Therapy/Rehabilitation* theme. 46.81% of videos within this theme involve intense physical movement and could directly inspire exergames [473] and physical rehabilitation serious games for health [6]. Dance was mentioned in 41 videos (often due to viral dance challenges) and could be an exciting design opportunity.

[5] https://tinyurl.com/y6lehk9p
[6] https://tinyurl.com/y6hzapoc

In Figure 9.2, the TikTok screenshot numbered 7 depicts two people with prosthetic legs racing each other [7]. The TikTok screenshot numbered 8 in Figure 9.2 shows a person with Parkinson's using a screen overlay filter to navigate a digital maze in a 1-handed planking position controlling a dot with their movement to build strength and work through tremors[8]. The first video represents a play potential that has not yet been augmented by technology. In contrast, the second showcases a play potential that has already been augmented, but could be improved with further iteration to include scoring, leader boards, social challenges, maps with dynamic difficulty, sensors, or badges. People naturally appropriate tech, such as camera filters, for their own goals that might not be the original use case, such as turning a maze game into an exergame. Designing playful tech with flexible affordances can lead to novel use cases that can improve our well-being.

9.4.5 Impossible Challenges

Posts that showcase people with disabilities attempting to complete tasks that they physically cannot do without tools or assistance are categorized into the *Impossible Challenges* theme. What is interesting about these videos is that the demonstrations can potentially educate the general population through empathy [474]. They showcase how disabilities can impair someone and provide a virtual sensitizing exercise by supplying *outsiders* with experiences that allow them to adopt the perspective of someone with a disability supporting *mine/thine* strategies [475]. The public perception of disability can be improved through exposure and mutual understanding. Work in this area has the potential to motivate policy that provides reasonable access and lessens discrimination toward people with disabilities [476].

[7] `https://tinyurl.com/yxtd5yyn`
[8] `https://tinyurl.com/y3heaven`

In Figure 9.2, the TikTok screenshot numbered 9 depicts a person who is colorblind sorting candy by color[9]. The TikTok screenshot numbered 10 in Figure 9.2 shows a deaf person trying to produce animal noises such as a pig's oink or a cat's meow—a true challenge given they have never heard the sound and are unable to hear their own imitation[10]. These videos might spark an education around disabilities by prompting questions such as "If you cannot see red and green, how do you drive?" or "How do deaf people learn to pronounce words?"—which people did ask in the comments. These are important conversations.

9.4.6 Perks of My Disability

Sometimes our disabilities can give us superpowers. There is a common misconception that disability is the opposite of ability [476], but a disability is a physical or mental condition that affects a person's movements, senses, or activities. The *Perks of My Disability* theme holds content that amplifies moments that creators feel empowered and more able than those without their disability. The example numbered 11 in Figure 9.2 shows a person using their prosthetic foot on the hot pavement to give their other foot a break from the heat[11]. Another humorous example includes a video of an amputee detaching her prosthetic during a game of Twister to gain an advantage [12]. As a society, we should celebrate perks of disabilities, such as the unique visuospatial abilities of people with autism [477]. Well-designed assistive technology has the potential to empower people with disabilities uniquely.

[9] https://tinyurl.com/y4sz66xz
[10] https://tinyurl.com/y3oso8n2
[11] https://tinyurl.com/yxejuxtk
[12] https://tinyurl.com/y58zn2xg

9.4.7 Duet Differences

By definition, the affordances of technology shape how people use it [478] and appropriate it, which became necessary for our analysis because people with disabilities used TikTok's "Duet" feature to juxtapose their own video with others'. There are two primary ways people with disabilities used the "Duet" feature: to share their real-time reactions to another post or to explain how they do an activity differently from someone doing the same activity in another post. When posts used the duet feature to highlight something about the creator's disability, the video was categorized into the *Duet Differences* theme. There are no such things as groups on TikTok, and creators use the "Duet" feature to create communities within the social network. In Figure 9.2, the TikTok screenshot numbered 12 depicts two people who are C5 quadriplegics comparing how the same diagnosis affects their dancing abilities[13]. The TikTok screenshot numbered 13 in Figure 9.2 shows two people with cerebral palsy completing a dance challenge to raise awareness about their disability. In both of these examples, people with the same disability highlight their differences, while at the same time fostering a community of education and growth around disability awareness on TikTok.

9.5 Design Concept Catalog

We created 20 design concepts based on play potentials found from scraping TikTok for playful videos featuring content creators with disabilities and share eight of my favorite concepts in this chapter. These concepts are meant to illustrate one method of engaging populations with disabilities, to inspire possible future technologies, and to advocate for inclusive and accessible general technology design. Our goal was to create a variety of ideas, so we did not constrain ourselves to the

[13] `https://tinyurl.com/y2emowms`

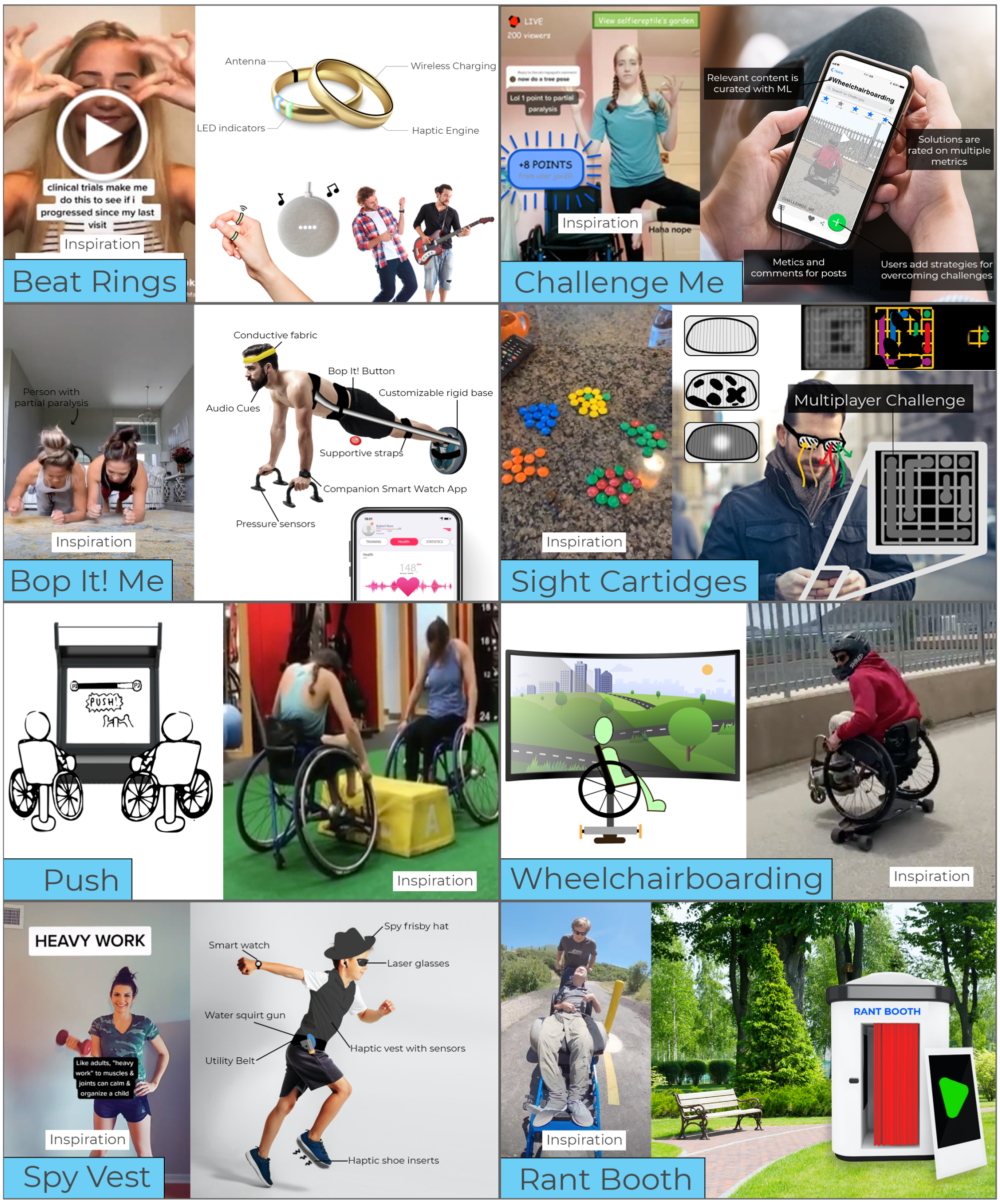


FIGURE 9.3: Compilation of our catalog of design concept sketches that are individually described in the text

limitations of current technology or a particular platform. We also did not limit our ideas to only accessible technology or only assistive technology, though some of the concepts indeed could be described as accessible or assistive. Our work is *generative*—while some of our concepts could feasibly be prototyped with today's technology, iterated on, and evaluated by stakeholders, the purpose of this work is not to build and evaluate a system, it is to envision and speculate possible future designs [19] and to add to a larger body of work calling for disability-inclusive

TABLE 9.2: Overview of design concepts

Name	Target Population	Medium	Themes	Visibility Potential	Therapy Potential
Beat Rings	General Population Physical Impairments Sensory Tool	Tangible Audio	Theater Sketches Gamification Duet Differences	Yes	Yes
Challenge Me	People with Disabilities General Population	Screens	Debunking Stereotypes Impossible Challenges Duet Differences	Yes	Yes
BopIt! Me	General Population Physical Impairments	Wearables	Gamification Impossible Challenges	Yes	Yes
Sight Cartridges	General Population	Wearables Mixed Reality	Playful Advocacy Debunking Stereotypes Impossible Challenges Perks of my Disability	Yes	No
Push!	General Population Wheelchair Users	Arcade	Gamification Perks of My Disability	Yes	Yes
Wheelchairboarding	General Population Wheelchair Users	Arcade	Theater Sketches Playful Advocacy Debunking Stereotypes Perks of My Disability	Yes	No
Spy Vest	General Population	Wearables Internet of Things	Theater Sketches Gamification	No	Yes
Rant Booth	People with Disabilities General Population	Tangible Internet of Things	Playful Advocacy Debunking Stereotypes Impossible Challenges	Yes	No

design [177, 181, 273, 274, 479]. In this section, we describe a subset of our design concepts and reflect on the unique elements of each, but provide a broader discussion as part of the Discussion section of this chapter. Table 9.2 provides an overview of the concepts, including the populations they could be relevant for, the technology mediums that might be interesting to implement each of the designs in, which of the themes described above the design supports, whether or not the design has the potential to increase the visibility of people with disabilities in society, and whether or not the technology has the potential to be assistive to people with disabilities.

9.5.1 BeatRings

Beat Rings was inspired by a person with a neuromuscular disease called Friedreich Ataxia tracking her hand coordination progress by tapping her fingers to a viral challenge called the "#transitionChallenge" that requires a person to tap each hand at a different rate [14]. People, regardless of their disability status, participated in the viral TikTok challenge, and we hypothesize that *Beat Rings* could be enjoyable

[14] https://tinyurl.com/y4wsw3ne

broadly. The sketch in Figure 9.3 shows the original post that inspired this design, a mockup of *Beat Rings*, and how they might be used in a social setting. We envision *Beat Rings* to be unobtrusive rings worn on fingers and embedded with accelerometers to detect tapping and wireless communication abilities to be able to communicate with smart speakers and other smart devices. Users could wear as many rings as they wanted on whichever fingers they want to record actively. Each ring can be assigned an instrument or a riff, and users can play by tapping their fingers to their thumb or tapping on any other surface. Users can create *Guitar Hero*-type challenges to battle with friends or jam together without needing to know how to play an instrument.

9.5.2 Challenge Me App

The *Challenge Me App* is a social media concept that fosters communities of people with disabilities to skillshare, similar to DIY culture. It was inspired by many play potentials found within the *Everyday Theatrical Life Sketches* theme. Figure 9.3 shows one of the posts that inspired the design and a mockup of what the app could look like. The app would foster creativity by leveraging our collective nature to develop the best solution to a specific challenge. For example, opening a door without arms could be a challenge for which the app collects solutions that can be upvoted for dimensions such as originality, creativity, cost-effectiveness, complexity, delivery, accessibility, dependability, and independence. The app has the potential to foster innovation within the community, foster community building, skillshare, and inspire better assistive technology.

9.5.3 Bop It! Me

Bop It toys are a line of audio games that issue a random series of pre-recorded audio commands to press buttons, pull handles, twist cranks, spin wheels, and flick switches on the toy quickly as the pace of the game and the player's score increases. *Bop It! Me* is a design concept inspired by a TikTok viral dance challenge where a person with partial paralysis completed the dance with the help of another who moved their legs for them. The concept idea, shown in Figure 9.3, features rigid body braces that would keep a person (paralyzed or not) in a plank position and from moving their lower body. The device has strategically placed *Bop It!*-style sensors such as conductive fabric, a headband for wiping one's brow, a button to bop one's hip, a sensor on a rotating base for one to "twist" or rollover, as well as an array of accelerometers to detect exercises such as push-ups. The device could support independent high scores, instructions for high-intensity, short-interval exercises, and exergames. It could be modular to customize sensors' placement and control how physically demanding the experience is. The frame could also be modular and provide rigid support for different ability levels and challenge levels.

9.5.4 Sight Cartridges

Sight Cartridges is inspired by TikToks showcasing glasses that allow people who are colorblind to see color for the first time[15], empathy tools for simulating various vision impairments [480], and the asymmetrical virtual reality game titled Keep Talking and Nobody explodes [481]. The premise of this concept, shown in Figure 9.3 is a game where players collaborate to solve visual challenges wearing glasses that afford them different visual privileges, such as being able to see color, to see a wide field of view without center clarity, or to see some areas sharply without a wide field of view. The glasses would have interchangeable cartridges that simulate different visual impairments to be used in the game and could also be used outside the game as empathy tools. Players with visual impairments would not need to use the glasses. The game itself could have various themes such as nanobots with

[15] https://tinyurl.com/y5wqg2cb

different abilities working together to find their target, alien creatures adapting to a new planet with multiple stars, or coming to terms in a new life inside the Matrix with malfunctioning brain-computer interfaces.

9.5.5 Push!

Push! is a design concept inspired by a TikTok showcasing two wheelchair users pushing against a yellow block in a strength competition where they try to move the block into the other player's territory similar to *Tug-of-War*[16], shown in Figure 9.3. This design concept would be found in an arcade where sensors are used to keep high scores, and the game could feature narratives such as personifying a bulldozer, racing as a locomotive, or spinning the wheels independently to generate music. This design concept has the potential to increase the visibility of disabilities in a safe public space, allow people to experience a wheelchair, and compete against actual wheelchair users (who would most likely win) on an equal playing field.

9.5.6 Wheelchairboarding

Wheelchairboarding is based directly on a TikTok video showcasing a person in a wheelchair placed on top of a skateboard speeding down the road laterally and steering by tilting forward and backward on the balanced wheelchair[17]. This design concept is another arcade game similar to other racing arcade games that simulate various vehicles, shown in Figure 9.3. This game has the potential to have the same visibility and empathy benefits described in *Push!*, but also has the potential to provide a safe space for wheelchair users to practice skateboarding.

[16] `https://tinyurl.com/y5p7xeky`
[17] urlhttps://tinyurl.com/y2hu5gu4

9.5.7 Spy Vest

Spy Vest is inspired by a series of TikToks from mothers sharing ideas and strategies for raising children with autism spectrum disorder, such as finishing chores before getting the WiFi password or creating soothing sensory experiences. Many of the mothers expressed difficulty motivating their children to get physical activity. *Spy Vest*, shown in Figure 9.3 is a wearable design concept featuring earbuds, accelerometers, haptic feedback, and a water squirt gun that can be enabled and disabled by the tech. The vest feeds secret missions to the child through the earbuds and uses the sensors to validate that the exercises are being performed. As a reward, the child gets a final puzzle that unlocks the WiFi and allows them to shoot water at their parents and siblings.

9.5.8 Rant Booth

Rant Booth is inspired by TikTok videos featuring people with disabilities ranting about the public infrastructure that handicaps them and from videos where content creators find strangers in public spaces and interview them about their lives and donate crowd-sourced funds to those in need. *Rant Booth*, shown in Figure 9.3, is a private booth located in accessible public spaces that playfully lures people in and prompts them to rant about challenges in their community. The booth would create a montage of humor-themed animations and altered voices using machine learning sent to policy-makers and local officials, prompting them to invest in a more universally accessible infrastructure based on community feedback.

9.6 Discussion

This chapter's primary purpose is to advocate for the design of playful technology for and to build designer empathy for people with disabilities. Technology development should include people with disabilities as stakeholders, and technology designed with and for people with disabilities does not always need to be serious. "Disability is a natural part of the human condition resulting from that spectrum—and will touch most of us at one time or another in our lives. The goal is not to fixate on, overreact to, or engage in stereotypes about such differences, but to take them into account and allow for reasonable accommodation for individual abilities and impairments that will permit equal participation"[476]. My first research question, RQ1 (*What play potentials exist from scraping content on TikTok from creators with disabilities?*), involved unearthing playful content from people with disabilities on TikTok. There were three strategies available to us for finding these posts: 1) searching keywords in the form of hashtags, 2) "favoriting" videos that met our criteria to train the "For You" page's curation algorithm, and 3) following content creators with disabilities. The process created an interesting feedback loop between us and the curation algorithm that likely uses machine learning. In some ways, in our work, the algorithm took a research assistant's role because it sought out data for our study. The massive scale biases and assumptions the algorithms foster likely impacted our work. There have been numerous news articles that describe how the TikTok algorithm suppresses the voices of those with disabilities, most likely due to how the general population interacts with content from people with disabilities. Massive-scale interactions with people with disabilities may have the potential to train the curation algorithms to show content from people with disabilities to the general population more often, creating more visibility.

My second research question, RQ2 (*What themes emerge from DREEMing on* *scraped play potentials and how does the TikTok platform influence the results?*), involved analyzing the TikTok posts we logged to sort them into 7 emerging themes, highlight exemplars, rate the level of "performativity", and tagging technological mediums that would be interesting to design for. I found that content on TikTok is generally performative, exaggerated, and dramatized, indicating that our design concepts are more likely to elicit these types of experiences. TikTok is likely a less appropriate platform to find play potentials that inspire more introspective designs. Many of the play potentials we found are about how people with disabilities are playful *with* social media—that is, they involve social media—which is very different from being playful *without* social media, possibly limiting the scope and applicability of our themes.

My third research question, RQ3 (*What kinds of designs can the scraped play potentials inspire and how might these designs affect society?*) began with using the exemplars to inspire design concepts. The eight design concepts are just that—concepts—they were inspired by people with disabilities and contain expertise from formally trained designers, but they are jumping-off points for future work in their current state. Soon, when technology and sensors' abilities can support these designs, the concepts would need to be evaluated, vetted, and iterated on with stakeholders in the target population. The design catalog can also serve as a conversation piece for facilitating discussions around speculative futures [19]. I begin this conversation by speculating on some of these potential future implications in the next section.

9.6.1 Possible Implications of Design Concepts

A common theme in two of our design concepts was using arcades as a safe space to facilitate disability visibility, understanding, and empathy. Arcades are shared spaces where people of many ages, genders, and cultures come together to play. Arcade games can be accessible to those with various disabilities and can host games that emulate assistive technology and devices for everyone to experience. These games can allow people with and without disabilities to play together, fostering relationships and friendships.

Many of our concepts could be enjoyed by both people with and without disabilities, such as the *Beat Rings* and *Spy Vest*—and could be played socially by peers regardless of their disability status. One key design goal for possible future implementations of these concepts is modular designs that are flexible to accommodate many use cases and ability levels. For example, the *Bop It! Me* concept uses a frame that allows different rigid supports for those with movement impairments. People are naturally adept at leveraging and appropriating affordances to accommodate their needs. For example, most creators with disabilities used the "Stickers" video editing feature in TikTok to create closed captions for their videos even though it does not natively support them. Some of our concepts are designed to be used exclusively by people with disabilities, such as *Challenge Me* , which fosters community building and skill-sharing.

Interestingly, there are many similarities to the *enhance the play* step proposed in the Situated Play Design methodology [333] in the enhancements content creators made to their performances. Many of the posts were clearly re-enactments, scripted, and dramatized to make them more entertaining. This is similar to *enhance the play* because content creators made mundane, everyday life more fun, suggesting that people without formal design training and people with disabilities are natural play chasers. Now, with the global epidemic, it is more evident than ever that we need more joy and play in our lives—and content creators are bridging this gap during these stressful times with their heightened and playful performances. Technology design that supports playful performances, as some of our design concepts illustrate (e.g., *Beat Rings, Challenge Me, Bop It! Me,* *Wheelchairboarding, and Spy Vest*), should support performers who have disabilities as well. Through continued exposure to designs that support performers with disabilities, our societies may build a greater understanding of disability as a political concept, advocate more for equitable access, and become more inclusive.

When augmenting the play potentials we found, we did not prioritize designs that served pragmatic goals. All of our design concepts have the potential to improve the public image of people with disabilities, foster empathy within communities, and promote play, which is generally beneficial—all of which are the primary motivations of this work. The *Rant Booth* concept represents a playful technology that could directly influence policy-makers and community leaders who have the power and capital to make a more accessible infrastructure. Based on the nature of the content we scraped on TikTok, where people with disabilities often showcased how they deal with their disability, some of our design concepts could be considered assistive technology that could serve a pragmatic purpose. For example, *Beat Rings* can help people with fine motor impairments, *Bop It! Me* can help improve stamina, and *Push!* can improve strength.

The results confirmed our hypothesis that TikTok is a performative platform where the content tends to be exaggerated, dramatized, and elevated. The emerging themes and the resulting concepts were directly fueled by performative TikTok content, impacting the demographics that might be interested in the futures our designs may support.

9.6.2 Limitations

This work's most prominent limitation is that we did not directly engage with people with disabilities—we indirectly scraped their content from TikTok. People with disabilities have not yet evaluated our concepts, and when appropriate, the specific target populations they could impact. In this work, our priority was to maintain a safe distance from these populations who often are at higher risk of COVID-19, and to refrain from placing any extra burdens on them during these stressful times, while still gaining design inspiration and insight. The goal of our work was to *generate* concepts that might inspire future technology, using existing content from these communities to inspire technology design, and to support our research agenda that general everyday technology should be playful, inclusive, and sometimes, non-utilitarian. Instead of a formal evaluation, we engaged in speculative design [19] practices to evaluate the potential of the design catalog.

The design concepts are intentionally vague in many ways. We did not design every interaction, affordance, and detail. We designed speculative design concepts that can serve as inspiration for future technology or as discussion probes. When it comes time to bring designs to fruition, a participatory approach should be used and include people with disabilities. Our design concepts were intern-led and directly inspired by exemplar TikToks they selected. More experienced designers may use our data set to generate novel ideas based more broadly on our emerging themes and their expertise.

Much of the scraping, brainstorming, and design work was completed by high school students participating in an 8-week summer internship. There are many exciting insights documented in their logs and reflections and our experience doing DREEM work with them. The internship also served as an entry point into empathy for people with disabilities. There was much growth and learning with each of the interns during the 8-week internship, which speaks to DREEMs potential as a pedagogical tool.

9.7 Conclusion

We collectively scraped content on TikTok from content creators with disabilities for 100 hours (5 interns for an hour a day, 5 days a week, for 4 weeks), resulting in 285 video posts containing *play potentials* [333] (RQ1). We analyzed and organized the posts into seven emerging themes: *Everyday Theatrical Life Sketches*, *Playful Advocacy, Debunking Myths and Stereotypes*, *Gamification of Therapy/Rehab*, *Impossible Challenges*, *Perks of My Disability,* and *Duet Differences* (RQ2). Finally, we created a catalog of 8 design concepts inspired by some of the *play potentials* and speculate on how they could inform the design of future playful technology that supports people with disabilities (RQ3). We found that content creators are natural performers and play chasers. We discussed how our concepts have the potential to inspire designs that can facilitate disability visibility, understanding, and empathy—and the importance of this potential impact on society cannot be overstated. These contributions add to a larger body of work advocating for the inclusion of people with disabilities in the design process. I provide the first data set of TikTok posts focused exclusively on content creators with disabilities being playful using the Situated Play Design and DREEM methodologies.

9.8 My Role

I served as the lead researcher in this work and mentored the high school students over an intense summer internship program. Ferran Altarriba Bertran also provided some mentorship to these students. The high school students, under my supervision, scraped the content and came up with design concepts. I conducted the thematic analysis with them and iterated on their concepts to create the design catalog.

Chapter 10

Reflection

In this chapter, I synthesize some of the overarching reflections that cut through the numerous projects presented in this dissertation. In this section, I begin by tying my case studies to my resulting design methods, SPD and DREEM. Next, in Section 10.1, I situate my insights in the beginning stages of the design process and I evaluate how the early approaches I took for my case studies impacted the resulting designs, providing considerations that future creators might find useful. In Section 10.2, I share some extrapolated facets of the social affordances from each of my case studies. Section 10.3 outlines how my doctoral research will serve as forward momentum for continuing this work in my future career. Finally, I share the conclusions of this thesis in Section 10.4.

The contributions of this research are two-fold: applied, and methodological. The applied contributions encompass developing the artifacts that make up my three case studies and the resulting lessons, described in each respective chapter and synthesized in Section 10.1. The methodological contributions in many ways also stem from the applied work in each case study—working on the three case studies enabled me to contribute to the creation of SPD and DREEM. Situated Play

Design was formalized around the same time that I conducted the cascading participatory design protocol for SpokeIt that included the tangible handcrafted design probes the children played with in the clinic. The intentionality behind the probes, particularly the felted game characters, shaped the resulting designs we prototyped. The context provided by the clinic where children did speech therapy and the probes directly influenced the research. Context is important for designing for play. These insights, along with those from the co-creators of SPD guided its formalization. Similarly, for DREEM, my work on each case study informed the method's creation. Each case study focused on a new population of people with disabilities and for each project, I was concerned with developing appropriate empathy and in-depth medical knowledge so that I could create a design intervention. Participatory Design can provide some of this knowledge, but it relies on disabled labor and, in many cases, reinventing the wheel. Using food to better understand diverse cultures and social media to better understand the play potentials of urban spaces served as inspiration for formalizing DREEM. In summary, each project, in many ways, bled into the next, and strengthened the successive work. I believe the famous idiom applies: "Hindsight is 20/20"—if SPD and DREEM were available to me prior to starting my doctoral work, my case studies would likely be stronger because they would incorporate a stronger lens of disability justice and meaningful play. After all, the purpose of creating new design methods is to enable innovative and novel work.

As a reminder to the reader, the guiding questions (GQ) of this work were:

GQ1: *What considerations should one make when deciding between a health-first approach versus a game-first approach?*

GQ2: *What considerations should one make when deciding between an open-ended play approach or a closed-game system?*

GQ3: *How can we design play for health that supports us socially and emotionally?*

GQ4: *What role should machine learning play in applications that support people with disabilities*

In the subsequent sections, I add some of my insights to these overarching guiding questions enabled by my doctoral research. These insights represent a reflection of my RtD-led agenda, but are not definitive. All but GQ3 are discussed in Section 10.1 and GQ3 is discussed in Section 10.2.

10.1 Evaluation of Approaches

Designers often make things for communities they are not a part of. As an individual without disabilities in the assistive technology field, I have grappled with my place. I have been concerned with respectfully approaching the domain of health as a relatively healthy person. Therefore, much of my work has been concentrated on the process at the beginning of a design project—how to approach the design of technology for play and health. Therefore, many of the insights offered by this doctoral research lie in the early stages of the design process. In the chapters six through nine of this dissertation, I employ SPD and DREEM to create speculative design catalogs that also represent early stages of the design process—precursory to potential participatory design. I am fascinated by the early stages of design because I believe they truly steer and shape the outcomes. Thinking well in advance is critical in design that interacts with society—we have great power and responsibility when we make new artifacts. Through this research, I have learned various approaches one can take in creating health applications and have started to develop a sense of when different approaches, design methods, and considerations should be used over others. Figure 10.1 depicts the approaches I have taken and where each design falls in this space. In this Section, I share some high level reflections on some of the different approaches I have taken at the beginning of the design process and how they impacted later artifacts.

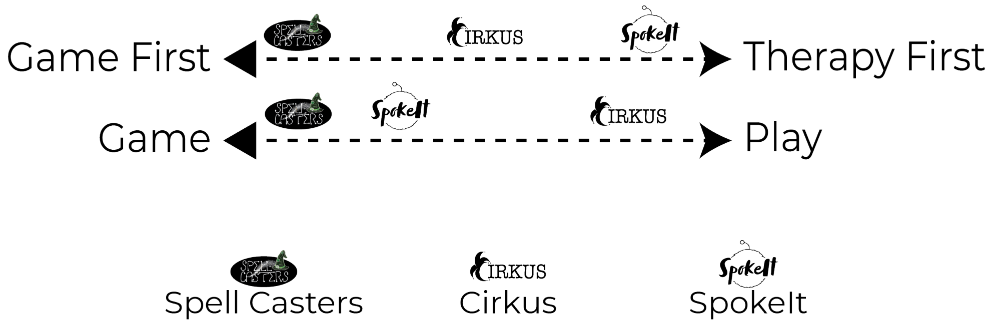


FIGURE 10.1: Approaches I've taken in creating Serious Play for Health systems and where each case study fits

10.1.1 Game First Versus Therapy First

A game first approach is one where an artifact is developed primarily for fun and is then retrofitted for a serious purpose. This is often a game created for leisure and then adapted to work for a specific population. There are many ways to adapt the game, but the most common is probably using alternative controllers and alternative input to make the game's mechanics therapeutic. Game first approaches often require alterations to the game itself and may require source code, which can be difficult to obtain, understand, and modify. A therapy first approach is more common in academia. When designing with a therapy first approach, the serious purpose of the artifact drives the design process. The functional requirements are typically gathered from medical professionals and stakeholders and drive the design of mechanics that will improve health. When this approach is taken, the mechanics are typically designed first and then the game elements, such as graphics, narrative, and systems are designed around the mechanic—all of which can be designed with the stakeholders and players. In a Serious Play for Health system, the design process may stop after the mechanics have been designed, so that the system remains flexible to many contexts, though some game-like elements may be added as well to suggest types of play.

Spellcasters takes a game-first, romantic (or designer-centric) approach while SpokeIt takes a therapy-first approach where user-centered, participatory methods were favored. Cirkus explores building an appreciation for the circus arts that secondarily results in improved therapy outcomes, which is why Cirkus sits in the middle of the spectrum. Game-first approaches should primarily be considered when source code is available, and the alterations needed to adapt the game for therapy use would be minimal. In these rare situations, the cost of creating the therapy game can be greatly reduced, but the alterations may ruin the very qualities that made the game enjoyable in the first place. In user-centered approaches, many of these risks are mitigated by the iterative process and stakeholder involvement which ensure the game is (hopefully) made right in the first place but results in a much higher cost for time and development. As described by Bødker, participatory sessions must be meaningful to the participants, not just the potential of the research [274]. Participatory projects are often so costly and time consuming in research that the product is never finished and never released meaning much of the time invested by the stakeholders is made less valuable.

10.1.2 Closed Game System Versus Open Ended Play

A game approach is more structured and rigid than a play approach. Game approaches are most common because the nature of full systems afford control over ambiguity. Automatic data collection is natural. Game approaches often rely on system sensing and technology to judge performance of therapeutic mechanics. Play approaches leverage ambiguity to afford flexibility and appropriation by many different stakeholders. Play approaches are typically systems that have design affordances that promote serious mechanics and may or may not be able to sense performance. Some rely on performance logging from a human.

Spellcasters is a closed system whereas Cirkus has been designed with open-ended multiplicity in mind. SpokeIt was originally designed as a closed game system but attaching a game controller allows expansion of the magic circle. Therapy games that follow the closed system typically follow the patient-care model and take the role of the medical professional by facilitating every aspect of the experience. This approach has benefits such as finely tuned user experiences, validated metrics of efficacy, and controlled magic circles, but runs the risk of frustrating players who are not accurately sensed or who feel they are being "fixed by technology". The less common, open-ended play approach allows players and facilitators to use the technology for their own contexts, increasing flexibility and adoption, capitalizing on surrounding expertise, and reaping the benefits of social play, but running the risk of unpredictable usage—and therefore a much more challenging research space.

10.1.3 Integration of Machine Learning

Much like any technology, based on its design and implementation, machine learning can create huge societal problems or serve our needs. The very nature of machine learning is normative—it places us into generalized buckets based on trends and patterns (read potential stereotypes). Being normative does not necessarily carry any ethical weight. However, the application of a normative tool can. Machine learning has historically amplified societal prejudices and been applied to unsuitable applications. The data used in training these models was prejudiced because our society is prejudiced. The people who train machine learning models are usually operating in a capitalistic environment with supporting agendas. Machine learning is a tool that has historically been wielded improperly.

There is also much promise for machine learning. Machine learning does not need to serve capitalism, societal injustices, or one privileged body. Machine learning can be designed using input from all populations it will impact. It can be transparent about confidence. Machine learning can augment our labor.

My first case study, SpokeIt, more closely follows the medical model than my third case study, Cirkus does. SpokeIt's machine learning critically evaluates speech and diagnoses speech errors. This process is normative as speech therapy is normative. However, the integration of this model dynamically adjusts difficulty and celebrates success. It gives insights into how one can improve their speech. The first acoustic models employed by SpokeIt were racist because they were critical of accents, but an accent is not a speech impairment. Training the model on more diverse data from our intended population improved the model. Cirkus takes an entirely different approach to machine learning. It is incredibly inaccurate and useless from a medical standpoint, but it serves well as a play potential and as a pipeline for future participatory machine learning. Cirkus can transparently display the confidence it has and the buckets available. The machine learning in Cirkus serves the population more than the researchers or medical professionals. Machine learning is a novel tool and there is promise for employing it ethically with disabled populations.

10.2 Social Affordances at Play

The difference between single player and multiplayer approaches may be obvious, but the effect the two have on play experiences and healing is interesting. In thinking through how each of my case studies supports social play, four spectrums can be extrapolated, shown in Figure 10.2. In symmetrical play, all players have the same set of actions and perspectives. In asymmetrical play, players have different roles. In competitive play, players try to win or make other players lose.

Sometimes collaborative games have competitive elements. In simultaneous play, players can take actions at their leisure and do not have to wait for their turn. In sequential play, players must wait their turn to take certain actions.

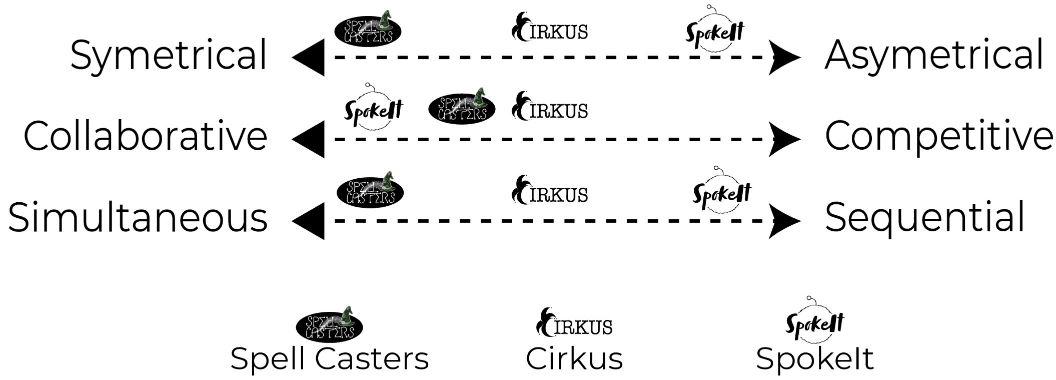


FIGURE 10.2: Extrapolated social affordances from each case study

10.2.1 Single Player versus Multi-Player

Spellcasters is exclusively multiplayer. SpokeIt was originally designed to be single player, but the addition of the game controller opens up social play potentials. Like Spellcasters, Cirkus is multiplayer. Single player experiences seem to be more common in the field of Serious Games for Health because they offer finely tuned user experiences, precise data controls, and controlled magic circles much like closed game systems. They typically follow the medical model, supporting a single patient, to control the intervention. Social play has the potential to improve our health, create more interesting play experiences, and allow for shared expertise, but risks negative play, complicates data collection, and can be a challenging design space.

10.2.2 Symmetrical versus Asymmetrical

SpokeIt's controller allows for both symmetrical and asymmetrical play. The person holding the controller can create symmetrical play by doing the same activities with the other players or they can create asymmetrical rules such as challenges appropriate for each player. Cirkus also supports both symmetrical and asymmetrical play as these are supported settings in the app. The multiplicity of Cirkus is specifically designed to afford many games and play potentials. The facilitator can elect leaders, lead an activity themselves, or let the app lead the activity. The performance grading can be completed by many different sets of people. The performers who move like animals can be individuals or groups and can be a uniform animal or all different animals. Spellcasters is symmetrical in that everyone is a wizard, but asymmetrical in that each wizard has a custom set of spells and medical professionals are able to define new gestures. Asymmetrical gameplay can potentially benefit Serious Health systems because they can allow players with diverse sets of abilities to play together by leveling the playing field, such as the arcade games in the speculative design catalog inspired by disabled creators on TikTok.

10.2.3 Collaborative versus Competitive

SpokeIt is generally collaborative because the player is trying to help the game characters although the facilitator could potentially create competitive situations using the game controller. Spellcasters is collaborative because the facilitator creates gestures that are custom for each stroke survivor. The original version of Spellcasters was both competitive and collaborative because two teams competed against each other. Cirkus can either be competitive or collaborative depending on the game that is created. Cirkus's purpose is to collaboratively collect representative movement data for machine learning. Collaborative play is a beneficial structure in the context of healing because it can be used to place one's abilities in a positive light as players are contributing to some greater good, whereas competitive play might frustrate those who lose based on their ability or disability. However, competition can be extremely motivating.

10.2.4 Simultaneous versus Sequential

Spellcasters is exclusively simultaneous because all players can independently cast spells at their leisure. SpokeIt is sequential because it waits for input, responds, and repeats. However, it is possible for a facilitator to create simultaneous mechanics, but this does not seem as likely. Cirkus can be both simultaneous and sequential. The tech automatically cycles through performing, evaluation, and reporting, so in some ways, Cirkus is always sequential. Simultaneous play may be more immersive because players can keep playing and do not have to wait their turn. In the context of health, simultaneous play may be frustrating if some players can take actions faster than others, putting some at a disadvantage. Sequential play offers structure that may aid in facilitation and provide ample time to take actions for each player's diverse needs.

10.3 Forward Momentum

My research is grounded in Human-Computer Interaction (HCI) and explores the intersection of social computing, health, and play. To better understand the complex, intersecting dynamics at the heart of disability, technology, and healthcare, I forge interdisciplinary research teams and community partnerships to develop a more holistic understanding of how to address the long-standing barriers faced by populations of people with disabilities. When we think well about how and what we design, we have an opportunity to make technology that is a cost-effective, personalized, data-driven, connected, and motivating context for otherwise tedious and repetitive wellness routines. I employ RtD to build and study systems that aim to improve the experience and effectiveness of meeting or maintaining health goals. This agenda is challenging because:

1. Too many existing systems prioritize the medical model of healing over the lived experience of having a disability
2. Among disabled communities, there is a vast variety of needs, abilities, behaviors, attitudes, and contexts of use that often change over time—these are difficult to model and translate into systems
3. Measures of success are complicated by the interconnectedness of Wicked Problems, including healthcare, disability justice, and sociotechnical system limitations

Considering these challenges, my research has three approaches:

1. I draw from interdisciplinary fields including the humanities, social sciences, and engineering to develop methods of inquiry and research agendas aimed at addressing authentic problems faced by people with disabilities
2. I design and develop technical probes that afford meaningful interactions and mechanics towards making therapy, rehabilitation, and healing more rewarding and effective
3. I innovate creative ways to utilize everyday, low-cost, reliable, and ubiquitous technology to gain insights into user behaviors as they relate to health, rehabilitation, and quality of life

My approach to research is to build real systems and prototypes that address authentic problems and opportunities for engaging with the needs of people with disabilities. I believe that cross-discipline and cross-cultural collaborations hold the key to new perspectives, innovation, and high-quality research. I work in partnership with community members and stakeholders through community-based frameworks to serve as a conduit for reaching their goals—my research benefits from acknowledging the expertise of groups, both within and outside of academia.

In my future research, I will continue to focus on disabled communities to better understand and build technology that supports and expands social support, care, and health. A key component of this work will be building long-term, reciprocal relationships and partnerships with communities of people with disabilities and organizations who support these populations—I will also maintain my already established connections. I plan to include a wide range of students on projects, from undergraduates through advanced Ph.D. students. My lab will specialize in creating playful assistive technology rooted in an understanding of critical disability studies and interdisciplinary collaborations and partnerships.

10.3.1 Open Play Structures that Support Wellness, Machine Learning, and Disability

Drawing from several streams of my research, I will design technology probes that transparently collect sensor data while people with disabilities play games aimed to improve their health. I will design these probes to be open-ended to afford many possible contexts and scenarios for appropriation. The data will be used to train machine learning models that can serve as the "antagonist" embedded within these probes—the messy data will undoubtedly make inaccurate models that can serve as a source of play where people can "battle against the technology" or create interesting results from the models' outputs. These probes will serve as exemplars for educating people on the follies of machine learning (opaquely placing people into inappropriate buckets) as well as provide insights into how democratic machine learning practices could be conducted and appropriately embedded in software.

10.3.2 Scaling Serious Games for Health

Too often, academic research with the potential to improve society never leaves the lab—the barriers, including protected health data, cybersecurity, bureaucratic logistics, intellectual property, operating costs, and entrepreneurial competencies are often too burdensome. Through collaboratively-created tools and services that communities can sustain as well as forging pipelines via my existing research products, I plan to ensure technology designed in my lab has broader impact and is studied in the wild. This work has the potential to better understand how Research through Design impacts real Wicked Problems and the interconnectedness of social computing, health, and play.

10.4 Conclusion

In this dissertation, I presented three case studies for designing and developing health applications for children with cleft speech, stroke survivors, and children with Sensory Based Motor Disorder. The resulting generalizable insights from these case studies enabled me to co-found two design methods situated early in the design process. These two design methods, Situated Play Design and DREEM, represent fertile ground for designing playful technology and technology that supports people with disabilities. In this dissertation, I have explored the utility of these methods through a number of case studies and speculative design catalogs. The program of research presented represents the outcomes of a research-through-design-led program of projects aimed at informing the next generation of systems that use play to support people with disabilities. The contributions of this work include designed artifacts with the potential to benefit society and design methods that can enable future creators.

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