From Margin to Center: Designing Inclusive and Equitable Service Robots with Disabled Adults

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To my parents, Richmond and Mavis: thank you for making me brave and encouraging my pursuits, regardless of whether you understand them or not.

Abstract

Service robots, autonomous systems that perform personal and professional tasks, have become a common sight in the Global North. In human-robot interaction (HRI), researchers rarely consider the design implications of service robots for people with disabilities (PwDs) beyond controlled assistive contexts, such as private homes and assisted living facilities. Nevertheless, the purview of PwDs transcends assistive contexts: PwDs know from lived experience that autonomous innovations can cause real harm to members of the disabled community when deployed. Therefore, considering the lived experiences of PwDs, many of whom exist at the social margins of society, can enable the design of inclusive service robots. Even so, robotics design practice can be exclusionary for people who are neither roboticists nor robot design practitioners.

Participatory design (PD) or cooperative design ("co-design"), an equitable approach aimed at shifting power relations and integrating community interests in the design process and outcomes, is becoming commonplace in HRI. However, HRI design practitioners who work with PwDs seldom interrogate whose lived experiences are represented in the design process, commonly privileging the experiences of professionals, such as technical experts and medical practitioners; this further encodes normative biases about how PwDs may want robots to behave around them or the types of support they may desire. Instead, HRI design practitioners should center on the experience-as-knowledge of members of the disabled community within co-design processes.

In this thesis, I present the Lived Experience Framework as a PD methodological approach for designing service robots with disabled adults. I demonstrate the application of this framework by co-designing service robots with disabled adults across three domains: assistive navigation, last-mile delivery, and personal mental well-being. I highlight the principles of the Framework, which reflects an onto-epistemological commitment to re-position the experience-as-expertise of PwDs, including shifting power towards PwDs through accessible design communication; highlighting power relations, embracing tensions, and fostering meaningful engagements with PwDs with intersecting social marginalization; and encouraging reflexivity in the co-design process. Furthermore, I offer design guidelines and socio-technical considerations for developers and design practitioners who wish to create inclusive service robots and equitable human-robot experiences. This work is a purposeful demonstration of the meaningful contributions made by democratizing the design of enabling, yet disruptive, autonomous systems and a call-to-action for HRI practitioners who seek renewed commitments to PD as a transformative framework.

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Part I

Introduction and Background

1 Introduction

1.1 Motivation

"Marginality [is] much more than a site of deprivation. [...] it is also the site of radical possibility, a space of resistance." – bell hooks [190]

"The robots are coming" [139] may sound like a techno-determinist[1] refrain. However, for people living in the Global North, robots are already here. In restaurants, airports, hospitals, and homes, service robots – a category of robots that perform personal or professional tasks for people [300] – can be found cleaning floors, delivering food, and providing companionship. Although companies and researchers are quick to claim ubiquitous benefits of service robots for the general population, people with disabilities (PwDs) know from lived experience that these technologies are not always made with them in mind [120]. More so, PwDs – including a mobility scooter user whose path was repeatedly blocked by a delivery robot [100] or a blind Paralympian who was struck by an autonomous bus [262] – know that non-inclusive autonomous systems can cause real harm when deployed without considering the downstream impacts on PwDs [9, 100, 155]. Even still, disabled communities should not be forced to adopt non-inclusive technologies but should be involved in their development and empowered to reshape technologies that will affect their public and private lives. Moreover, international organizations have echoed concerns about the lack of safety, accessibility, and equity frameworks concerning service robots [162]. Unfortunately, PwDs are frequently excluded from participating in the design of these technologies due

[1] Theory that technological progress is inevitable and that people ought to acquiesce to new technologies [118], in this case robots [145, 151].

to structural factors [124], such as inequities in accessible education. In the United States (US), only 3% of the total STEM workforce have a disability [324]. Furthermore, robot design practice can be intimidating [89], especially for PwDs who are not robot design practitioners and are unaware of the jargon and design processes.

In human-robot interaction (HRI), participation of PwDs is considered primarily within the assistive context [360]. Despite assistive robots being within the broader category of service robots, the purview of PwDs extends beyond the assistance they need from a robot. Instead, the lived experience of disabled people can capture the many ways that the world can and has been inhospitable to so many people who exist at society's periphery: people who are marginalized or who live in under-served communities[2]. Therefore, creating technology with people at the margins of society captures scenarios and contexts that are overlooked by many due to bias. The lived experiences of disabled people, those who occupy the margins of society, should be centered because doing so makes technology more inclusive and equitable for everyone.

One poignant example of the design for the margins that resulted in more equitable outcomes is that of curb cuts, the small ramps that divide the sidewalk and roadway. The history of curb cuts in the U.S. reaches far back into at least the 1940s [5, 424]. In few communities across the U.S., members of the disability community, such as disabled veterans returning from World War 1, drove the implementation of ramped sidewalks [5, 424]. However, in the 1960s, disabled student activists in Berkeley, California, advocated for curb cuts as a safe and efficient means to allow wheelchair users to cross the streets [424]. Unfortunately, some of the first curb cuts were wide and flat [424], making it difficult for white cane users – people with visual disabilities – to distinguish the end of the sidewalk.

After several iterations, driven by disabled advocates, we now have the curb cuts we know today: sloped regions, with flared sides, that occasionally features a rectangular area with raised bumps painted a vibrant yellow. Curb cuts provide an accessible means for mobility device users to safely cross the street. Furthermore, the raised bumps with vibrant yellow paint provide tactile and visual contrast for distinct transitions, which can be invaluable for people with visual disabilities. In addition, curb cuts also support pedestrians with a range of dis/abilities, micro-mobility users on bikes or scooters, and people pushing

[2] I use "marginalized" to refer to people who are socially, economically, and politically disenfranchised [190]. Furthermore, we use "under-served" to refer to communities or populations that have reduced access to equitable resources, such as education and healthcare [302].

their babies in prams. It is no wonder that these architectural features are frequently used as an example of universal design [389], an inclusive design practice that seeks to design solutions that are usable by as many people as possible. It is important to note that **universal design artifacts are the product of pluriversal design processes**. Only by designing for the plurality of humanity, especially those at the social periphery, can we create outcomes that are beneficial for the majority of us.

However, re-designing systems that you encounter in your daily lives, such as the sidewalks you use daily, may be simpler than re-designing complex technical systems, like robots, with which you may have no experience. How, then, should we expect a person with a mobility disability who uses a mobility scooter and is not a robot design practitioner to re-design a delivery robot that repeatedly blocks their path along a sidewalk? Or a person who is blind and white cane user who does not notice a robot waiter[3] because it made no sound when it approaches their table? **To understand how we design inclusive service robots, we have to answer how we make the design process of complex technical systems more inclusive.**

Important Note: In this thesis, I use **person-first** (e.g. 'people with disabilities') and **identity-first** (e.g. 'disabled people') language *interchangeably* to reflect the diversity of preferences of disabled peoples and communities [39]. This acknowledges both the personhood of people with disabilities and disability as an identity. Although this work is focused on inclusive service robots as "disability-related technology" [431], there are several critical justice-oriented frameworks that draw from critical theory that must be acknowledged to ensure that these technologies truly support <u>*all*</u> disabled people and do not further marginalize and subjugate them.

1.2 Problem Statement

> *"Design is with and by people, not for people; the role of the designer is facilitator, not decider."* [298]

The lived experience — subjective experience composed of a person's emotions, perceptions, preferences, and goals [207] — has been used to define the "design site" [141] and the context for the design ideation [141]. In human-centered design practices, such

[3]This narrative comes from a participant who is blind who described his experience with inaccessible robot waiters.

as participatory design (PD) and user-centered design (UCD), it is common for design practitioners to use the lived experience of potential-end users as inspiration for design ideation. Therefore, lived experience is treated as the source of inspiration and defines the context and site of design ideation [141]. However, in UCD, the designer has design-making power decisions. Despite UCD being a descendant of PD, they have different goals. Participatory Design (PD), or cooperative ("co-design") [69], is a democratic approach that aims to disrupt power imbalances in the design process and integrate community interests in design outcomes [51, 69, 115, 175]. In recent years, HRI design practitioners have incorporated both PD and user-centered design (UCD), into their robot design practice (e.g. [28, 29, 172, 238, 318, 320, 426]). Despite PD that encourages disruption of power relations between community members and designers, HRI design practice tends to value professional expertise more highly than potential end-users [74, 172, 353, 360, 440]. Similarly, within disability-related robotics (i.e. assistive robots), the expertise of non-disabled medical professionals [421, 422, 423] and caregivers is commonly relied upon to define the interaction specifications. However, in these contexts, the participation of PwDs is relegated to that of the "expert user" [40, 431] and burdened with evaluating technologies and ensuring that these technologies are usable [32]. The lived experiences of disabled people, their knowledge, and contributions are also frequently exploited without being credited [431]. Moreover, privileging the experiential knowledge of non-disabled professionals over disabled people reinforces normative expectations around the support PwDs desire in their daily lives. Thus, HRI design practice still has a way to go to answer both equitable design processes that result in inclusive robots more broadly and service robots more specifically.

In PD, a critical aspect of disrupting power relations is prioritizing a process of *mutual learning* between researchers and communities through partnership and shared understanding [51]. Through this process, end-users should learn about novel technologies that may impact their lives, which should result in empowerment, whereas researchers should gain experiential knowledge from end-users. Mutual learning enables end-users to participate equitably in the design process by understanding existing systems and possibilities, which can enable them to envision alternatives [51]. Some HRI researchers using PD approaches have encouraged mutual learning in co-design [238, 320] and have incorporated feminist principles [427], such as intersectionality [97], an analytical framework that considers intersecting social privileges and oppressions introduced by the legal scholar and Black feminist, Kimberlé Crenshaw. However, this has not drastically changed the way PD workshops are conducted in HRI [427].

In technology design practice, PD workshops hinge on "blue sky" ideation [175] (i.e., imagination unbridled by social or economic constraints), which further marginalizes already under-served communities [175] by making them envision infeasible futures. Furthermore, in disability-related technology, the lack of critical engagement with the histories and material conditions (i.e. their socioeconomic statuses) of PwDs, many of whom face social, economic, and political marginalization, allows superficial design engagements that center technology as a panacea without confronting the realities of their lived experiences [328]. Therefore, even PD engagements that seek to remediate unequal power relations between practitioners and potential end-users fall short by assuming an "ideal" user that can serve as the basis for universalist claims. Even within inclusive frameworks "inclusive," [43, 431] potential end-user can be neatly slotted into a single sociodemographic category (e.g. "Blind," "Black," or "poor"), seemingly to avoid the messiness of lived experience. Thus, the lived experiences of PwDs are reduced to help the designer create technologies while claiming universal benefits [142, 167, 408] while failing to service most PwDs [431]. However in critical theory frameworks, such as Critical Disability Studies (CDS), the lived experience is not simply about understanding the realities of disabled people; it is a site of social transformation: "[the] lived experiences and attempts to transform the circumstances under which oppressed subjects live through critical [and] intersectional analysis. Complicating this expansive approach, accountability to disabled persons is paramount to this work" [286].

Therefore, failing to engage with the entirety of PwDs' lived experiences leads to technologies with affordances that are highly specified for an idealistic, non-existent potential end-user and woefully under specified for the "messy," complex, real end-user. Therefore, beyond providing design inspiration [141], prioritizing the lived experiences of PwDs is vital to ensure technology design (or refusal [38, 297]) contributes to their social transformation [286]. Therefore, in echoing the ethos of Critical Disability Studies (CDS): I argue that HRI design practitioners who do not want to recreate the social exclusion of PwDs through robot design "should address exclusion by centering disabled people as experts-by-experience in their own lives" [418]. Furthermore, critical technology researchers, who have attributed failures in PD used technology design research, including HRI, to a hyper-fixation on the critiquing of power relations between designers and potential end-users [328], urge us to also "[confront] the onto-epistemological foundations that sustain oppressive technological systems" [328]. Simply put, they argue that it is imperative to recognize that what people know (i.e., their being/realities, or the "onto") is inextricable from knowing/knowledge (i.e. "epistemology") [223]. Therefore, in pursuit of re-committing to participatory design as a democratic <u>and</u> emancipatory framework [51], we must be judicious in *whose* lived experiences are centered in the design process and how that shapes technology.

1.3 Research questions

In this thesis, I engage the lived experience of disabled adults who are not robot design practitioners as (1) a site of design inquiry; that is, their lives define the design context where we cooperatively design service robots. We draw on their experiential knowledge: their memories (reflection-on-action), technologically-mediated or not, their perceptions and beliefs, and their desires and goals. Furthermore, In this process, I recognize that as we design service robots, HRI design practitioners who aim to recommit to PD as an emancipatory framework must center the lived experiences of those at the social margins if we desire equitable and inclusive technologies. Therefore, in this pursuit, I emphasize the (2) expertise-by-experience of PwDs gleaned by engaging their lived experiences and center this in their shaping of their technology-mediated futures.

To this end, this thesis aims to answer the following research questions:

RQ1: Does grounding co-design of service robots in the lived experiences of people with disabilities result in inclusive and equitable design guidelines?

RQ2: Does prioritizing the experience-as-knowledge of PwDs make the process of co-designing service robots equitable?

In this thesis, **I argue that centering the lived experiences of disabled adults during the co-design process leads to more inclusive service robots and equitable human-robot interactions**. I illustrate participatory design processes that leverage the experiential knowledge of non-roboticist PwDs to design service robots used across three distinct domains: assistive navigation, last-mile delivery, and mental well-being. Specifically, the research focuses of this thesis include designing (1) guide robots with people who are blind or have low vision (pBLV), (2) delivery robots with people with mobility disabilities (PwMDs) and pBLV, and (3) co-designing social robots with Black women with anxiety and/or depression (BWA/D). Through this work, I reveal that situating design ideation in the lived experiences of disabled adults produces inclusive design recommendations.

1.4 Orienting the Reader: Terms & Domains

In this section, I will provide the various ways that disability is defined. Despite misconceptions about what disability may look like, disability is diverse and nuanced. For example, there are several types of disability, some of which are "visible," many of which are "invisible." Some categories of disability may include (1) sensory disabilities, such as visual and hearing disabilities; (2) mobility and physical disabilities; (3) neuro-developmental [3] (e.g. Autism Spectrum Disorder (ASD), Attention-Deficit / Hyperactivity Disorder (ADHD), etc) and cognitive disabilities; and (4) mental health disabilities (e.g., mood disorders, anxiety disorders, etc).

1.4.1 Defining Disability

There are several models of disability. However, I focus on defining the two most common, especially as they pertain to disability-related technology research.

Models and Frameworks of Disability

In disability studies, an interdisciplinary field concerned with the social, historical, and cultural experiences of disabled people beyond medical diagnoses, there are two primary models of disability: medical and social [34, 266]. The medical model views disability as simply a physically-experienced "impairment" [365] that is problematic and must be rehabilitated [34]. In contrast, the social model argues that beyond "individual pathology"[4] [34], disability results from "social barriers and power relations, rather than an inescapable biological destiny" [34]. For this, scholars of disability studies argue that we

[4] In this case, "disease" or sickness

must consider disability as socially constructed; that is, disability is enforced due to barriers based on social identity, which have social, economic and political implications for disabled people [365].

Disability models have shaped broader understandings of disability. For example, the World Health Organization (WHO) outlined the International Classification of Functioning, Disability, and Health (ICF) [312], a framework for classifying. According to ICF [312], disability is classified according to three dimensions as follows:

1. "impairment", which are"problems in body function or structure such as a significant deviation or loss"
2. "activity limitation" "are difficulties an individual may have in executing activities"
3. "participation restrictions" are "problems an individual may experience in involvement in life situations"

Disability has been defined as permanent/long-term and temporary (e.g., a broken leg). However, disability has also been conceptualized as "situational" within the context of accessible computing and applied to interactive computing [428]. For example, a "situationally-induced disability" may occur when a person has trouble hearing conversations in a noisy bar. Although this framing may support accessible interaction design, it does not fully capture the lived experience of disabled peoples, specifically aspects that are influence by social factors (e.g., identity [392] or oppression [78]).

1.4.2 Defining *Service Robots*

According to the International Organization for Standardization (ISO), a service robot (SR) is one that is for "personal use or professional use that performs useful tasks for humans or equipment" [300]. Personal use tasks include "handling or serving of items, transportation, physical support, providing guidance or information, grooming, cooking and food handling, and cleaning." Professional use tasks include "inspection, surveillance, handling of items, person transportation, providing guidance or information, cooking and food handling, and cleaning." Under this paradigm, service robots [263] include assistive and social robots.

Types of Service Robots

Assistive robots are service robots that can help PwDs with tasks in their daily lives. For example, physically assistive robots provide functional assistance to PwDs; this includes aiding them with performing acts of daily living (ADLs), such as using the bathroom, ambulating (i.e., moving around), and eating. In addition, socially assistive robots (SARs) provide psychological (i.e., mental, emotional, cognitive) help through social interaction [268]. Still, as service robots become integrated into private and public life in the Global North, PwDs are likely to encounter them beyond the assistive context. Therefore, service robots should be inclusive for PwDs, whether they are the intended end-user or a bystander.

1.4.3 Defining *Inclusive* & *Equitable* & Roots in Disability Activism

"Nothing About Us Without Us" is a slogan popularized by activists during ongoing Disability Rights Movements (DRM). Nevertheless, this slogan has roots in the idea that social policy should not be created without inclusive, full, and equitable participation of those whose policies will impact them. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) [1], "inclusive" refers to:

> *practices* or policies that actively promote the participation and representation of diverse individuals, regardless of their backgrounds or identities. In the context of social and human sciences, *inclusivity* aims to foster environments where everyone feels valued and empowered. This approach is essential for developing *equitable* social policies that address systemic inequalities and enhance community cohesion.

Similarly, in the social context, UNESCO [2] defines "equity" as:

> the *fair distribution of resources, opportunities, and privileges* within a society, ensuring that all individuals have access to the same rights and benefits regardless of their background. This concept is crucial as it addresses systemic inequalities and promotes *inclusivity*, aiming to create a more just and balanced community.

Therefore, inclusivity and equity are mutualistic; that is, inclusivity and equity are mutually dependent and mutually beneficial. Moreover, extending these concepts to disability-related technology, inclusive design practices must include equitable participation and representation as this is vital to remediating systemic inequalities caused by non-inclusive technologies. Disability technology scholars [40, 431] have noted the importance of equitable inclusive design in disability-related technology by critiquing failures of inclusive design methods:

> "inclusive methods continue to distance disabled people from the shared construction of knowledge through tokenistic forms of 'voice' that fail to redistribute power and agency to disabled people."

1.4.4 Why These Domains?

This work focuses on service robots that help with assistive navigation, last-mile delivery, and mental health. These domains represent fundamental tasks of daily life related, but not exclusive, to disability. For example, navigation is vital for transportation and facilitating the movement from one location to the next. Last-mile delivery is useful for providing access to resources for situations when people cannot or do not want to use transportation to acquire resources, and instead need the resources to come to them. Finally, mental well-being is an important fact of life for everyone, whether you have a disability or not. Thus, these tasks present a unique opportunity to explore how designing at the margins with PwDs can produce inclusive service robots as well as how to orient PD processes such that non-roboticist PwDs can more equitably contribute to the design process.

However, to truly understand why situating service design ideation within the lived experiences of PwDs, one must understand the material conditions of people in disabled communities worldwide and within the U.S in particular as the site where this work was conducted.

Disability Facts and Figures

In 2023, the World Health Organization (WHO) estimated that 1 in 6 people worldwide has a disability [314]. People with disabilities have disparate access due to systemic inequity (see social model of disability 1.4.1). PwDs face inequities in access to healthcare [314]. As such, they are more likely to have "comorbid" conditions, meaning that they experience additional health conditions. For example, disabled people are more likely than non-disabled people to be affected by health conditions such as asthma, diabetes, and stroke [314]. Furthermore, they are more likely to experience negative impacts on mental health, including an increased risk of depression, anxiety, and social isolation [314].

PwDs also face socioeconomic inequities due to discrimination in hiring, as well as disparate, often inaccessible, and inequitable education [314, 324]. In addition, they face several obstacles to equitable mobility. WHO reports that PwDs are 15x more likely to encounter transportation barriers due to lack of accessible features or financial barriers than non-disabled people [314]. In the U.S., 1 in 4 adults has a disability [91]. However, disability rates vary by sociodemographic group. For example, Black and Native American communities (25% vs. 30%) [137], who often live in under-served communities as marginalized groups, have higher rates of disability as a result of inequalities in access to economic and healthcare barriers [137, 314]. This also negatively impacts the mental well-being of PwDs; for example, only 1 in 3 Black adults who have a mental health disability were able to get access to mental health resources [99].

In Pittsburgh, the city where this work was conducted, 2020 census data [4] estimates that $\sim 20\%$ of the city's population is Black. However, almost 30% of people with disabilities are Black/African-American [138], showcasing their over-representation in the disabled population. In contrast, the representation of white people among Pittsburgh's disability population is commensurate with their presence in the general population: 60% of PwDs in Pittsburgh are white [4] and $\sim 60\%$ people in Pittsburgh were white. According to the 2023 Allegheny[5] County Quality of Life Survey, which centered on race [107], PwDs who face multiple marginalization, such as Black Pittsburghers, are also more likely to live in under-served communities with limited food access and transportation [107]. Nevertheless, Black Pittsburghers are almost twice as likely to report relying on public transit than non-Black Pittsburghers(42.4% vs 22.9%), despite disparate access to quality transportation [107].

Domain choices

These facts and figures highlight the motivation for my choices to focus my thesis work on these service robots domains. Moreover, these domains also represent support that anyone would utilize, including assistance getting around a new building independently, needing to order resources to your home, or needing mental well-being support. The specific disability

[5] Pittsburgh is located in Allegheny county.

communities that we focus on also reflect their lived experiences with systemic barriers in how the built environment fails to accommodate them, including barriers in equitable transportation and mobility as well as barriers in access to mental health and well-being support.

1.5 Contributions

This work embraces calls for inclusive and equity-centered service robot design guidelines [162] AND equitable design frameworks for ensuring the participation of marginalized peoples, in particular socially diverse people with disabilities (PwDs). I contribute the Lived Experience Framework as a methodological approach for designing service robots with disabled adults. Through this work, I reveal that situating design ideation in the lived experiences of disabled adults produces inclusive design recommendations. By conducting short-term, longitudinal participatory encounters, we further anchor design ideation in lived experiences of PwDs. This has shown to produce service robot designs that are uniquely tailored to their present needs and how those evolve over time.

Contribution One: The Lived Experience Framework, a PD methodological approach that re-positions the experience-as-expertise of PwDs who are not robot design practitioners in the co-design of service robots.

Methodological Framework Summary

The Lived Experience Framework is intended to enable PwDs who are non-professional designers to participate in the co-design process on "equal footing" with co-designers with technical expertise (e.g. roboticists). This framework applies the following design principles:

1. Shift power towards PwDs by using *accessible ideation materials* while de-centering technical materials at the outset of the design process.
2. Highlight *power relations*, *embrace tensions*, and engage *PwDs with intersecting social marginalization* [116, 126].
3. Finally, encourage *self-reflexivity* in researchers and participants [116, 126].

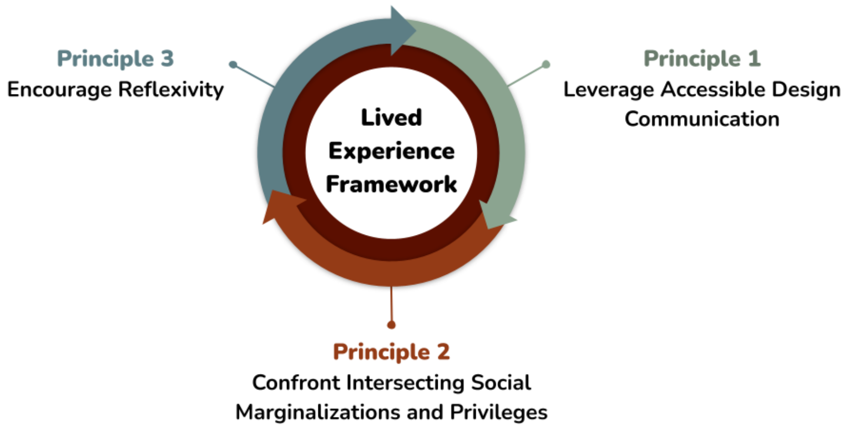


Figure 1.1: Summary of the three principles that comprise the Lived Experience Framework.

> **Contribution Two:** Inclusive and equitable design recommendations for service robots resulting from applications of the methods that comprise the Lived Experience Framework.

1.6 Thesis Organization

In this work, I demonstrate that lived experiences can be used to both specify the design context and sites (i.e., the specific tasks they wish to complete and the use environments), *and* identify specific guidelines for the design of supportive physically embodied agents. The lived experience, which comprises the subjective (e.g., goals, preferences, perceptions) and embodied (e.g., emotion, bodily sensations) experience, serves as a basis for co-design activities with PwDs who are non-designers; the lived experience is both the design site, but it is also the basis of design ideation. Thus, interrogating people's lived experiences (e.g. through participant reflective engagements) can provide insight into how to design robotic technologies that support and assist them in their lives. The structure of the dissertation is described below.

Chapter 2 introduces a review of the theoretical foundations of lived experiences across philosophy and critical study; furthermore, I demonstrate how these foundations are applied in technology design practice and human-robot interaction (HRI). Next, I provide an overview of inclusive and equitable design frameworks, in particular participatory and user-centered approaches. I describe how these frameworks are applied in HRI, while underscoring the importance of applying these approaches to disability-related HRI research.

In the next two chapters, I demonstrate how I utilize the lived experience as a means of designing service robots with PwDs; in particular, I focus on the domains of autonomous mobility, namely first-mile transportation (i.e., assistive navigation) and last-mile transportation (i.e., delivery). In Chapter 3, I present an inclusive, scenario-based approach to co-designing service robots for assistive navigation (i.e., "guide robots") with blind and low vision (BLV) adults; I demonstrate that verbal descriptions, in lieu of physical design artifacts, act as a low-fidelity, accessible medium for participants to explore and iterate on ideations rooted in their experiential knowledge of navigation. In Chapter 4, I extend this low-fidelity methodology by introducing multi-modal ideation toolkits to enable diverse people with disabilities to co-design service robots for on-demand, last mile delivery (i.e., "delivery robots"). Furthermore, by recruiting socially diverse adults with visual, mobility, and hearing disabilities, I demonstrate how engaging people with intersecting social marginalizations (i.e. disability and race/ethnicity/gender) informs their lived experiences and subsequent service robot designs and equity-oriented factors.

Next, I present work focused on service robots used in mental health contexts. In Chapter 5, I provide motivations for social robot-mediated mental health, the value of social robots that support mind-body activities for anxiety and depression, which are characterized by emotional dysregulation, and the importance of engaging marginalized groups in the design of these technologies. In Chapter 6, I leverage theory of mind (TOM) as an approach to capturing the people's lived experiences, including their perceptions of robots' social behaviors, to evaluate and identify necessary socio-cognitive factors for improved acceptance of socially intelligent robots used in mental well-being contexts. ToM is a human's ability to understand another person by attempting to infer their mental states, including their emotions, desires, and intensions (e.g., [106]). Finally, in Chapter 7, I integrate findings from these chapters to co-design socially intelligent robots to support the mental well-being of marginalized populations, specifically Black women with lived experience of anxiety and/or depression. I apply the fully-realized Lived Experience Framework to address gaps in how socially intelligent robots can support marginalized populations. Furthermore, I highlight how structural issues, such as barriers to mental health, cannot be solved by robots; instead, roboticists should seek to understand the lived experiences of impacted community members to co-create technologies that complement their socio-technical desires for increased access.

In closing, I end this thesis by reflecting on how these chapters address my research questions. Chapter 8 situates my thesis work within the broader context of disability-related technology design and HRI; furthermore, it provides a summary of the design guidelines and socio-technical and equity-oriented considerations and risks. Finally, I close by describing the limitations of this work and present future opportunities and directions to implement and extend the contributions of this work.

This thesis aims to synthesize lenses from multiple disciplines, including HRI, human-computer interaction (HCI) psychology, interaction design research, while also drawing from domains with roots planted in critical theory, such as Critical Disability Studies and other critical design and social justice frameworks (e.g. decolonial and pluriversal, speculative, feminist, etc) [77, 94, 116, 298, 399, 403, 406], towards inclusive and equity-oriented human-robot interactions.

2 Framing

2.1 The *Lived Experience* from Philosophical to Applied Technology Design

Lived experience, or experiential knowledge, has been a more common term used in qualitative methods research. In this chapter, I provide some historical and theoretical grounding for the influence of different perspectives from philosophy, critical theory and disability studies, design practice, and human-robot interaction (HRI). I explain the significance of the "lived experience" as part of philosophical study, the implications of it as part of the "social models" of disability, and the importance of incorporating first-person perspectives into design practice and the development of "assistive" robots for disabled people in HRI.

2.1.1 Lived Experience in Classical Phenomenology

The *lived experience* is rooted in classical phenomenology, a twentieth-century European philosophical movement [290]. Phenomenology is the philosophical study of the *subjective conscious experience*. According to contemporary phenomenologist, Dan Zahavi, phenomenology is "the science or study of phenomena" [434]. Phenomenology is concerned with multiple concepts that describe human experience and consciousness [433]. In this section, I summarize these key concepts.

Phenomena

This concept underscores subjective experience. A phenomenon is the appearance of the world. Phenomenologists reject the idea of a "two-world doctrine," the idea that the way the world appears is different than what can be empirically determined through scientific investigation [434]. Instead, phenomenologists claim that the *appearance of the world is reality*. Phenomenologists do not posit that the appearance is a fact, but instead that the phenomenon includes all the "required reality and objectivity" – the facts are simply a matter of analysis [434].

Edmund Husserl [195], who is credited as the originator of phenomenology, describes phenomena as follows:

> "experiences intuitively seizable and analysable in the pure generality of their essence, not experiences empirically perceived and treated as real facts."

Zahavi [434] describes phenomenology as being concerned with the "how" rather than the "what" of objects; that is, phenomenology is focused on how objects appear to a viewer rather than their objective properties. However, our subjective perceptions of the world are not constructed by these phenomena. Thus, our consciousness is not purely "self-directed," but is instead "self-transcending" and is concerned with objects and occurrences outside of itself. This leads to the next concept.

Intentionality

Intentionality is concerned with consciousness being "directed to" and "of" something [434]. This concept pertains to how our consciousness is directed towards and constituted by our perception of phenomena [434]. The concept of intentionality is crucial to "embodied phenomenology" [280]. Zahavi argues that "the body plays a decisive role in different forms of intentionality" [434]. Moreover, the act of perception is an "embodied activity" [434]. Therefore, the concept of intentionality underscores that there is no division between a person ("subject") who perceives and a body that perceives. That is, we do not perceive objects because we have a body, but because we are our body, thereby describing "embodied subjectivity" [434]. Intentionality forms ideas of the "mind-body dyad" and "self-other-world triad" [434].

The Living Body

The lived body is predicated on our understanding of both phenomena and intentionality. Our consciousness is directed towards and comprises (i.e., intentionality) our perception world (i.e., phenomena). The concept of the living body extends these ideas by describing our consciousness as "constituted by our relationship" to the world we live in. These ideas inform the concept of "embodiment." According to Zahavi, "the body is always present as that which makes it possible for me to adopt a perspective on the world" [434]. Furthermore, "pre-reflective experience" is "[t]he lived body [that] precedes the perceived body. Originally, I do not have any consciousness of my body. I am not perceiving it, I am it" [434]. Through the concept of the living body, we are introduced to the understanding that "being-in-the-world" means being with other people (and minds). This is the basis for *intersubjectivity*, or interpersonal interactions being integral to a shared/mutual understanding of the world, which is related to notions of "empathy" and social connectedness [434].

2.1.2 Lived Experience in Critical Disability Studies

Classical phenomenology is vital to the notion of the lived experience and the methodologies used in this thesis. Classical phenomenology failed to interrogate **how "history and power" influence the lived experience** [163] – a gap that Critical phenomenology aims to reconcile. Critical phenomenology asks: "if phenomenology offers us unparalleled means to describe what we see with utmost precision, to illuminate what is true, critique insists that we also attend to the power that is always conditioning that truth" [349].

Similarly to critical phenomenology, Critical Disability Studies (CDS) study how power and oppression shape the lived experiences of people with disabilities. As an extension of disability studies, CDS is a "location populated by people who advocate building upon the foundational perspectives of disability studies whilst integrating new and transformative agendas associated with postcolonial, queer and feminist theories" [156]. Moreover, Professor and Disability scholar, Julie Minich writes that CDS, "involves scrutinizing not bodily or mental impairments but the social norms that define particular attributes as impairments, as well as the social conditions that concentrate stigmatized attributes in particular populations" [286]. Furthermore, Minich writes that "scrutiny of normative ideologies should occur not for its own sake but with the goal of producing knowledge in support of justice for people with stigmatized bodies and minds." Thus, in this work, we draw on critical phenomenology, and CDS as an extension, to design with and from lived experiences of disabled peoples, which is in alignment with participatory engagements as rooted in liberatory frameworks [51].

2.1.3 Lived Experience in Technology Design Practice

The lived experiences of both potential end-users and design practitioners shaped methods used in technology design. For example, design practitioners encouraged reflection on their own lived experiences and implicit knowledge. Donald Schon, the originator of *reflective practice* [358] – a design practice with phenomenological roots – wrote about how designers utilize their own experiential knowledge by reflecting-on-action. This includes ‘reflection-in-action’, which enables participants to use their design intuition to “participate in design” [259]. Furthermore, this also encourages practitioners to engage with their experience and “reflect on the work they’ve done” [73]. These practices help inform “soft prototypes” [73], iterable, early concept designs. Reflective practice has informed methods, such as scenario-based design (SBD) [73, 74]; SBD encourages technology designers to use scenarios centered on a desired use context to evoke ideation and re-shape designs through intuition-guided iteration [73].

Furthermore, the phenomenological origins of the lived experience have reshaped technology design practice by reorienting design practitioners away from the third-person perspective (i.e., designers are observers who are designing for other people) [112] towards first-person perspectives (e.g., designing for one’s self within the context of their own experiences). For example, Paul Dourish, a computer scientist, described the phenomenological origins of *embodied interaction* [117], a method that has been prominently utilized in tangible and social computing. Moreover, embodied interaction has informed soma-based and body-based design approaches [188, 239, 375], which leverage embodied subjectivity towards meaning-making that facilitates design ideation [301].

Finally, the lived experience has shaped how co-design is conducted in technology design practice. For example, Sanders describes “experience design” [351] as a participatory approach leveraging the lived experiences of end-users to enable them to actively and “creatively” engage in the design process. Furthermore, Sanders describes the salience of accessing end-users’ both tacit and explicit knowledge to enable design practitioners to establish “empathy” with their users – a trend that disability technology scholars have critiqued for being patronizing [40]. Finally, reflective design practices [362] are powerful tools that have been used in critical technology design [185, 192]. Reflective practices encourage designers to reflect on their own lived experiences, including often invisible assumptions, which, unchallenged, can (re)produce harm through the technological design.

2.1.4 Lived Experience in Human-Robot Interaction

In Human-robot interaction (HRI), the human experience is commonly interrogated in several ways. One approach, from psychological and philosophical origins, is "Theory of Mind" (ToM), "the ability to ascribe mental states such as beliefs, desires and intentions in order to explain, predict and justify behavior" [19]. HRI researchers apply ToM to design algorithms to estimate a person's internal states, inducing their emotions, beliefs, preferences, and goals, which are directly related to features of their lived experience (see review [235]). Some example applications include detecting a person's emotion states to alter a robot's behavior to ensure improved feelings of safety and trust [224, 225, 226].

Recent efforts of HRI design researchers have explored the use of participatory design engagements for both design ideation and evaluations. For example, Ostrowski engaged older adults in longitudinal co-design and used their lived experiences with social robots in their homes to further inform their experiential knowledge about robots and shape their ideas. Although majority of these works focused on social robots used by elderly adults [238, 318, 320], some have centered on experiential knowledge of marginalized people, including women [237]. However, discourses interrogating ***whose*** lived experiences are centered in the robot design process are nascent in HRI, where it is still common to center the experiences of people from non-marginalized backgrounds (i.e., non-disabled, white, educated, technical experts, etc) [360].

2.2 Inclusive & Equitable Design Methodologies

2.2.1 Inclusive Design in Disability-related Technology: Accessible Computing

Across technology design practice, particularly in accessible computing [429], there have been several various inclusive design methods, many of which have origins in physical design practices (e.g. urban planning, architecture, etc). I will present a brief overview of these frameworks to contrast them with PD as an equitable design framework.

For example, Universal design [261, 389] has been used to design physical products and spaces that are “usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” [111]. However, critiques center on attempting to design “one size fits all” solutions [429]. Another framework is ability-based design [429] which re-positions focus on the “ability of end-users instead of focusing on “disability” [429]. Furthermore, a principle of ability-based design is concerned with inexpensive components and acknowledges the burdens of maintaining novel technology on disabled people. However, they focus on accessibility as integral to broadening the usability of products; they do not directly address equitable participation of PwDs within the design process.

2.2.2 Participatory Design and User-centered Design

PD is a collaborative approach focused on democratic decision-making to ensure that the interests of community members are represented in the design process [115]. PD evolved from Community-Based Research (CBR) and Participatory-Action Research (PAR) [93].

PD research was founded with **co-equal** commitments to *design*, *research*, and *political activism* [32, 210]. That is, design and research (‘knowledge-production’ [32]) should lead to interventions on issues that impact communities. PD has origins in Scandinavian countries in the 1970s. Here, cooperative design was used to empower workers to shape how computers were developed and used within their work [69]. In recent years, several HRI practitioners have incorporated participatory design (PD) and user-centered design (UCD) into their robot design practice. UCD is a descendant of PD used in technology design that is used to ensure that end-users are involved in the design process. However, the goals of these approaches are different. The PD process is facilitated to ensure equitable decision-making power between stakeholders and researchers. In contrast, UCD approaches are used to ensure that end-users are involved in the design process so end products are usable [51, 157]. In the context of disability-centered technology design, a commitment to PD means understanding the lived experiences of PwDs and working towards the transformation of their social circumstances through critical inquiry and action [65, 328].

HRI design practitioners have centered the lived experience of people who are not robot design practitioners in the co-design process [237, 238, 316, 318, 319, 320, 321].

Ostrowski et al. [318] conducted longitudinal co-design of social robots that were deployed in the homes of older adults; they wanted to understand how the lived experiences of 28 older adults was influenced by having a social robot, which lived in their home for 1 month; moreover, they wanted to capture how these longitudinal deployments reshaped older adults' knowledge about social robots and their desires for how these technologies could better support them. Over 12 months, Ostrowski engaged participants in a range of activities, such as interviews to discuss the roles social robots could play in their lives; participatory art-making for participants to articulate the emotional relationships with the robot across social contexts. Furthermore, Ostrowski also facilitated participatory (block) programming as a means of mutual learning with participants to increase the power older adults had in shaping social robots for their needs [318]. After deployment, participants iterated on social robot interactions. Finally, participants voted on the social robot design guidelines in groups [318].

Despite HRI design researchers using PD approaches, encouraging mutual learning [238, 320], and enabling centering expertise-by-experience of potential end-users, little engagement has been done with the material conditions of PwDs or how multiply marginalized PwDs face different barriers. Therefore, PD engagements in HRI still embody "blue sky" ideation [175] (imagination unbridled by social or economic constraints), which can further marginalize already under-served communities [175] by making them envision infeasible futures. Therefore, by embracing a commitment to engaging with onto-epistemology underpinning robot design practice towards equitable service robots, we must seek to engage people at the margins. Furthermore, we must critically engage with their lived experiences by facilitating self-reflexive discourses [192, 423].

2.2.3 Critical Design

> *"[A]ll design research and practice is culturally located and power laden, even if considered fairly general."* [199]

Critical design is "a research through design methodology that foregrounds the ethics of design practice, reveals potentially hidden agendas and values, and explores alternative design values" [33]. Moreover, critical design approaches are concerned with "provoking" [158], envisioning "alternative possibilities" [362]. In HCI, several methodologies are under the umbrella of critical design. They include speculative design [122], reflective design [362], and decolonial design [206, 378, 399]. However, in HRI, critical methodologies are sparse and emergent (e.g. [319, 427]).

Technology design researchers often fail to consider beyond "power relations" [328]; they fail to consider harms perpetuated by designs that replicate power inequities and harms. Thus, design researchers should consider beyond local power relations (i.e., between researcher and stakeholders); they should also consider how ideologies, assumptions, and biases perpetuate and sustain power structures [77, 116, 199, 328].

Critical design approaches have been used in HCI and disability-related technology research [423]. For example, reflexive critique has been used to critically reflect on disability-technology research. In particular, Williams and Boyd [423] participated in a mutually reflexive critique of four of Boyd's previous interventionist approaches to wearable and virtual reality (VR) headsets to encourage normative conversational behaviors in people with autism. These critiques are "reparative" analyses of Boyd's previous works, which resulted in "counter-interventionist modes of inquiry." The principles of counter-interventionist modes of inquiry encourage researchers and designers to reflexively engage with participants and their communities; critically examining the needs of disabled people versus clinical perspectives, which are often prioritized; interrogating the material conditions for disabled people (e.g. the political and cultural landscape); encouraging interventions as a self-critique (i.e. articulating disconnects between participant desires and research focus); and center the lived experiences people with disabilities (PwDs) as evaluation. As critical lenses are vital to equitable robot designs, we embrace counter-interventionist modes of inquiry by privileging the experience-as-expertise of PwDs concerning their technologically-enabled futures.

2.3 Summary

To summarize the gaps this thesis addresses:

1. Previous work highlights re-orienting design power towards potential end-users (i.e., older adults) using a range of inclusive PD approaches, including storytelling, speculative design, and longitudinal design engagements and deployments, and mutual learning activities [237, 316, 319, 320].
2. I extend previous equitable frameworks in HRI [316] by asserting that HRI practi-

tioners must be critical about *the* lived experiences we focus on within the co-design process. I focus on lived experiences of diverse PwDs as people at the social margins.

3. I extend previous equitable HRI frameworks by asserting that PD engagements rooted in the experience-as-expertise of PwDs leads to inclusive service robots and equitable human-robot interactions more broadly.

Part II

Designing Service Robots with Blind and Low Vision Adults

3 Co-designing Guide Robots with Blind and Low Vision Adults

Part of this work is featured in *Shih, K.*, Boadi-Agyemang, A.*, Carter, E., & Steinfeld, A. (2025). A Multi-Method Investigation of Guide Robot Characteristics for Blind and Low Vision Users. ACM Transactions on Human-Robot Interaction.* [369]

Navigating through unfamiliar environments is a challenging task. For people who are blind or have low vision (BLV), navigation can be particularly daunting. Guide robots are a type of service robot that can assist BLV people with navigation tasks. A significant amount of research related to guide robots has focused on technical contributions, while a dearth of research has centered on exploring the affordances BLV users desire from these robots. We conducted a two-phase user study with 16 BLV participants aimed at identifying features, functions, and behaviors of guide robots that enhance BLV users' sense of orientation, perceived safety, and comfort. The first phase centered on robot interaction, during which participants were guided by a robot along pre-computed trajectories (detailed in [369]). This work focuses on the second phase, which occurred after the participants experienced navigating with a guide robot that exhibited four different behaviors. In this phase, we conducted semi-structured interviews and participatory design (PD) sessions with each of the participants. The PD sessions utilized a scenario-based design (SBD) approach aimed at identifying ideal features and functionality of guide robots and a dialogue-simulated activity to verify these requirements. We identified three key themes that serve as design considerations for future robotic mobility aids for pBLVs: (1) features that enhance the usability of guide robot systems, and factors that (2) influence BLV users' desires for shared robot control and (3) enhance BLV users' perceived safety in public settings. Our work reiterates the importance of interactive PD approaches, such as SBD, for facilitating accessible idea generation and iteration when working with BLV populations.

3.1 Introduction

Navigating unfamiliar indoor environments is a difficult task regardless of one's ability. For people who are blind or have low vision (pBLV), navigating through complex, unfamiliar environments can be daunting. Navigation is a multi-fold task that comprises two key spatial aspects: locomotion and wayfinding. Locomotion is moving from one place to another while forming a mental representation of a space. Wayfinding involves using this internal representation of the space to move through this space, and includes planning and decision-making about one's path, avoiding obstacles, and altering one's speed of movement. Wayfinding is difficult for BLV people to do as it relies on their ability to form an accurate mental representation of the space. Without this, it may be difficult to plan one's route efficiently. As BLV people navigate from place to place, they may encounter various orientation- and mobility- (O&M) related challenges. *Mobility* challenges include avoiding static and dynamic obstacles, detecting changes in ground level, finding exits, and adapting to abrupt changes in the environment (e.g. changes in light intensity) [348]; *orientation* challenges involve one's sense of direction (e.g. "turn left"). BLV people use a range of mobility aids to assist them with these navigation tasks. These aids range from low tech solutions, including white canes, guide dogs, and sighted guides to high-tech aids, such as GPS devices, mobile device applications, and robotic mobility aids.

Innovations in robotics have focused on the design of guide robots, a type of service robot that assists BLV people with navigation tasks in indoor and outdoor environments [86, 165, 170, 411, 416]. While much of the research on guide robots has focused on the technical challenges and contributions of autonomous systems or acceptance of specific systems, very few focus on using participatory design (PD) methods to identify user and system requirements for guide robots [29, 229]. Furthermore, researchers also ought to explore how existing mobility aids can be used with guide robots to enhance the independence of BLV people as they navigate the world.

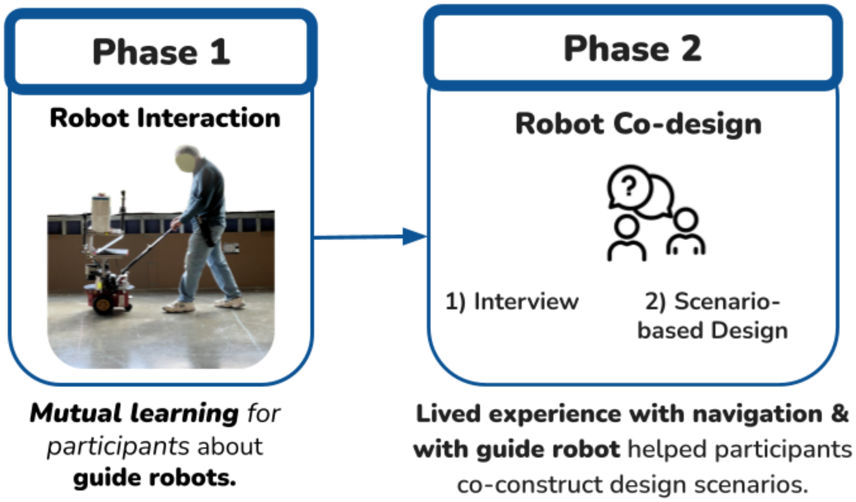


Figure 3.1: Our two-phase study approach. The Robot Interaction phase provided a mutual learning opportunity for our BLV participants. The Robot Co-design phase provided an opportunity to use their lived experiences being guided by prototype, in conjunction with their everyday navigation experiences, to envision new guide robot designs.

In this work, we focus on identifying ideal features of these guide robots, users' sense of orientation, and feelings of comfort and safety. We conducted a two-phase user study (see Fig. 3.1) with 16 BLV participants. The first phase – which served as a mutual learning experience for our participants – centered on a robot interaction, during which participants were guided by a guide robot prototype along pre-computed trajectories [369]. This chapter focuses on the second phase, during which we conducted semi-structured interviews and co-design sessions with each of the participants. Furthermore, we used a scenario-based design (SBD) approach to identify the desired interactions from beginning to end of interactions with guide robots. We then used a dialogue-based simulation activity to verify the identified requirements. We go into detail exploring the physical interactions with the guide robot. The contribution of this chapter is to provide insight and recommendations regarding the design of future guide robots, particularly regarding (1) features impacting usability; (2) users' desire for shared control; and (3) users' perceived safety in public settings.

3.2 Related Work

Guide robots offer benefits for blind people, especially in unfamiliar and complex spaces. However, few researchers have yet to highlight the importance of guide robots to blind travelers and how they envision its use within their daily lives. This work contributes an understanding of the various interactions, affordances, and use cases that pBLV desire from guide robots. We leverage simulated dialogues grounded in a scenario to probe and uncover the limitations. This approach has been used to support participatory design of novel interfaces between sighted researchers and blind users. Through this work, we aim to contribute to a growing appreciation for participatory research methods that de-center visual design artifacts and enable rapid iteration of early design ideas.

3.2.1 Participatory Design in HRI

In recent years, participatory design (PD) methods have been employed within HRI research, particularly towards the design of assistive robots and social robots [342]. While prior work has various PD approaches, particularly surveys [181, 201, 433], to gain insight into the preferences of pBLV for future navigational and mobility aids. BLV peoples' mobility strategies and preferences [201], preferred navigational aids, including mobile applications [433], and their desires from future robotic mobility aids, few researchers have employed in-person, iterative PD methods to verify and refine these ideations.

PD approaches have been used to identify desired interactions and functionality of robotic agents. When designing guide robots for people with visual impairments, Azenkot et al. [29] explored the use of participatory methods for building service robots (BSR) in effective and socially acceptable ways from the beginning to the end of the interaction. Participants engaged in familiarization with BSRs to understand their current capabilities, individual design sessions that focused on low level specifications of robot behaviors when guiding participants, and ended with a Wizard-of-Oz session to prototype the identified interactions with the blind users and gain feedback. Through these design sessions, Azenkot et al. identified various specific modes (sighted guide, escort, information kiosk) users desire from BSRs as well as specific user interactions (e.g. slowing down and speeding up). They also identified important features and themes, including desires for querying, robots that can support multiple navigational tasks (e.g. mounting stairs), and the utility of guide robots as public tools. This work demonstrates the importance of using PD methods for feature identification and specific interaction modes for service robots used by BLV people. Similarly to this work, we incorporate the Wizard-of-Oz methodology (WoZ) [387] to enable users to gain experience with an early prototype.

3.2.2 Inclusive Co-design Approaches in Technology Design

Despite the benefits of PD, including their importance to receiving timely feedback from users as well as engaging stakeholders in the design process, these methods can be time consuming, often requiring iteration on existing systems. Furthermore, Wizard-of-Oz and other prototype-oriented design methods can be limited by the demands of an existing hardware and software systems, as well as constraints in technological advancement. Scenario-based approaches have been used in HCI and human-centered design for the planning and evaluating of potential tasks and to and to help specify usability goals [343] and as an accessible means of designing with people with disabilities, particularly BLV users [282, 308, 346].

Sahib et al. [346] introduced a scenario-based design and dialogue simulation approach to facilitate design interactions between mixed-ability design teams (sighted researchers and blind users) for a proposed search interface. First, researchers and BLV users walked through a potential experience with a prototype of a search interface to identify key features. The BLV users articulated how they would ideally like to use this interface. After initial idea generation, the researchers and BLV users iterate on detailed descriptions of the features and functionality of the proposed search interface. Finally, the researchers crafted a unique scenario in which the BLV person would use the proposed interface as a way of verifying the system requirements. This scenario-based approach with dialogue simulation offers a way for the design team to evaluate the current interface and provide real-time opportunities to gain immediate feedback from the user. Kuribayashi et al. [229] used a similar scenario based approach to determine the design requirements of a mapless robotic navigation system to help blind people navigate unfamiliar indoor environments. This design approach featured an interview with sighted participants to understand how they would explain two routes to sighted versus blind people then using those descriptions to navigate blind participants and gain feedback on what they want from a robotic system that provided those descriptions. We use this approach, using detailed verbal descriptions as an accessible means of iterating on ideations with BLV participants. Furthermore, by de-centering physical artifacts, we aim to quickly iterate upon and update ideas to fit the needs of BLV users across various scenarios.

3.2.3 Identifying Safety and Comfort in HRI

Positive perception of safety is an important metric for whether robots can be accepted as partners or co-workers and impacts belief in whether users will adopt the agent [35]. Emotion detection by robots can enable the robot to tailor its behavior, crafting an experience that increases a user's perception of safety. A recent extensive review by Rubagotti et al. [344] focused on surveying aspects and themes of and related to perceived safety of autonomous robotic systems. They found that common terms used in physical HRI (pHRI) research that have been related to the notion of perceived safety include trust, comfort, stress or strain, fear, anxiety, and surprise. Within HRI, perceived safety has been measured indirectly using questionnaires [224, 225, 299], physiological sensing approaches [224, 225, 226, 299, 330], direct input devices [214], and behavioral measures. However, since current affect detection approaches have largely focused on sighted people, work still needs to be done to identify the modalities that would enable researchers to effectively estimate BLV user affect towards crafting user experiences that foster trust and user acceptance. Thus, we designed a two-phase user study to examine factors related to BLV people's perceptions of safety and comfort while using a guide robot. We use self-report measures to capture our participant's perceptions of their comfort and safety. Furthermore, we collected video data of participants while using the guide robot to perform post-hoc affect detection to identify key factors that influence these perceptions.

3.3 Method

We conducted a two-phase user study (see Fig. 3.1). First, we evaluated how specific aspects of guide robot paths might impact the user's comfort and orientation in space. Second, we leveraged the robot interaction experience as well as participants' experiences in daily life to identify important features of guide robot systems in general.

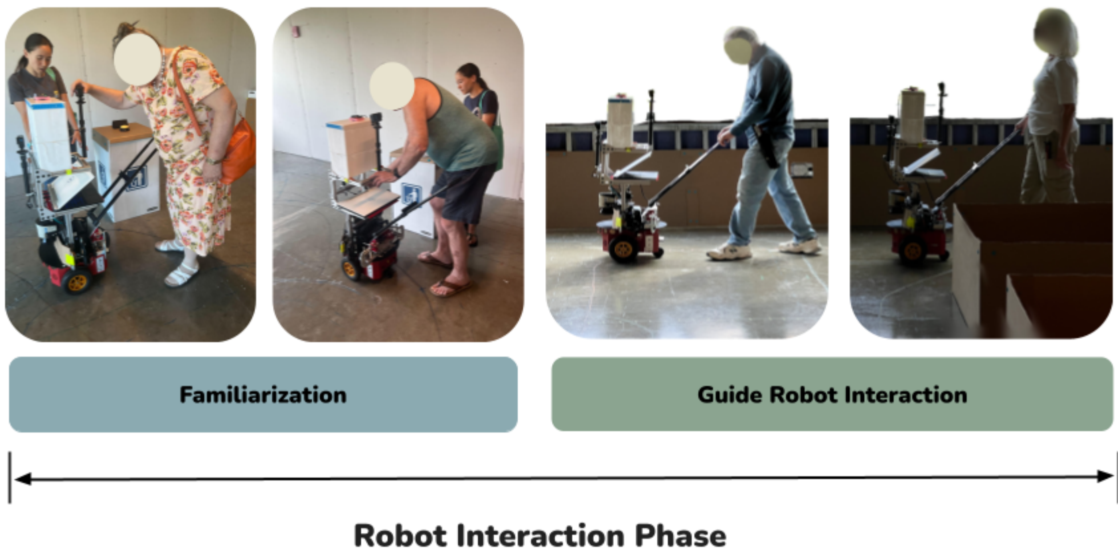


Figure 3.2: An example of the activities that comprised the robot interaction phase: familiarization and the guide robot interaction.

The study took place indoors on our institution's campus. Participants consented to the study on a secure survey platform prior to arrival. Upon arriving at the study location, the purpose of the study was reiterated and consent reconfirmed. Our study protocol was approved by our Institutional Review Board. It lasted up to 150 minutes and participants were compensated $90.

Participants were asked demographic questions and completed the Mobility-Related Quality-of-Life Measure for Individuals with Vision Impairments [245]. They were then introduced to the space where they would be interacting with the robot. Next, they were familiarized with the robot: first with a verbal description followed by the opportunity to touch and ask questions about the system, then by following the robot on a simple rectangular path. This introduction was followed by the robot interaction and participatory design phases of the study.

3.4 Study Setup

This study was conducted as a two-phase study. The first phase was a robot interaction; the second was a participatory design session. Although the first-phase was conceived as an experimental study aimed at understanding the impact of path planning strategies on BLV peoples' perception of mobility and safety (see [369]), it served as a mutual learning [51] opportunity in which the BLV participants could experience a prototype of a guide robot, which served as a technology probe [352]. The prototype was the Podi robot, which has a three-wheeled base with additional structures including clamps, beams, a suitcase handle, rear and forward facing cameras. The cameras are for mapping, planning, obstacle detection as well as to capture facial and body posture of the user during navigation. Users were guided by the robot by using one hand to hold onto the suitcase handle.

In the first phase of the study, participants followed the robot through a series of four courses constructed of cardboard obstacles laid out in a large indoor space (approximately 9x19m). The robot was teleoperated along pre-computed paths demonstrating four different robot behaviors [369]. After each trial, we administered the Questionnaire for the Evaluation of Physical Assistive Devices (QUEAD) [357], which is a 10-question Likert scale drawn from the Emotions, Attitude, and Comfort subscales that was intended to elicit feelings of comfort, safety, and acceptance. Participants were asked to verbally rate their experiences after each trial. Finally, we timed them to see how long it took each participant to return to their start position. The details of this procedure are described in [369]. After the robot interaction phase, we transitioned into the interview phase. First, participants were asked to reflect on their experiences with the robot in a semi-structured interview, as well as to clarify behaviors observed and comments made during the trials.

In the second phase of the study, we used a scenario-based design approach from [346] (see Sub-fig. 3.3A); participants were asked to talk through an imaginary interaction with a guide robot. Feature identification (see Sub-Fig.3.3B) questions focused on (1) requesting

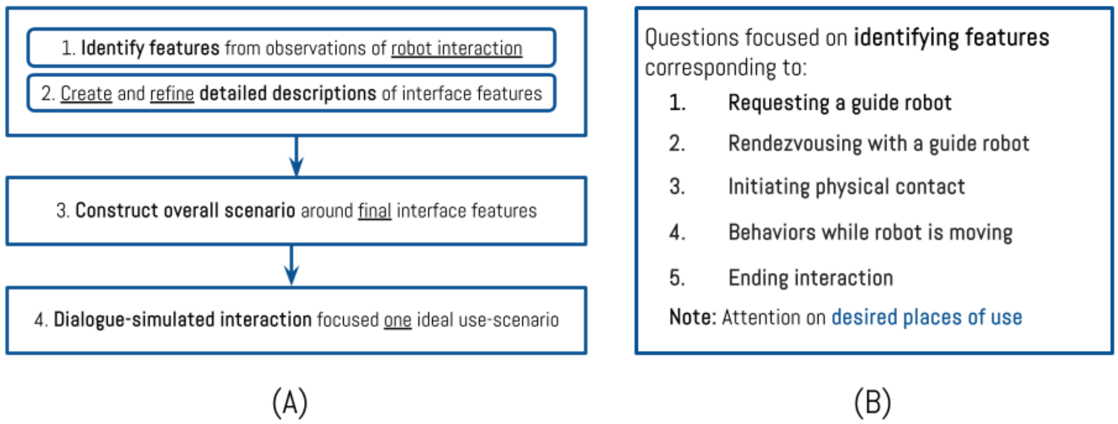


Figure 3.3: (A) Steps that comprise the scenario-based design approach used; (B) The guide robot interactions we focused on as part of feature identification.

the robot, (2) initiating contact, (3) finding the robot handle, (4) navigating with the robot, (5) approaching obstacles and crowds, (6) ending contact with the robot, and (7) identifying key places of use and challenges they face in those locations that could be assisted by the robot. At each step of the interaction, participants were asked how they would like the robot to behave and what features or functionalities they would include.

Finally, we verified system requirements through a dialogue-simulated interaction [346] between the researcher and participant by contextualizing the study's guide robot experience within a specific scenario. Participants were asked for locations where they would like to use the guide robot; of those suggested by a given participant, one was selected by an experimenter for discussion based on participant enthusiasm. Across the 16 participants, the subsequent dialogue-simulated interactions covered 9 unique scenarios (supermarket, airport, theater, baseball stadium, hospital, mall, university building, cruise ship, and bank). Participants were instructed to draw from their lived experiences with the study's robot and with navigation, more broadly.

3.5 Participants

We recruited 16 legally blind participants (eleven female, five male) from the local community. Five participants had no functional vision; 8 had residual light perception; and 3 were low vision with varying visual acuity and field loss. Participants used a range of mobility devices: 8 used both guide dogs and canes, 6 used only a cane, and 2 used neither. Most participants also used smartphone apps for navigation. Participants were between ages 35-78 years (mean 58.4, median 64). In general, participants were highly confident in their ability to navigate: scores on the mobility questionnaire ranged from 55 to 70 out of a possible 70 (mean 66.4, median 67.5). All participants except one self-reported being in at least one prior research study with a guide robot or navigational system. No participants were students at our institution.

3.6 Qualitative Analysis

Rich qualitative data was extracted from transcripts of the semi-structured interviews and participatory design sessions, as well as notes taken on participant comments during and after the robot interaction trials. Qualitative analysis was performed by three authors (of whom two were present during data collection). We performed iterative affinity diagramming [187] and reflexive thematic analysis [88] to identify themes and sub-themes. We began by coding the entire data set of qualitative findings. Researchers met over multiple sessions to identify, interpret, and discuss emergent codes and initial themes. We constructed a code book to ensure that researchers were keeping track of identified codes and their meanings. After we completed several rounds of coding, researchers clustered codes towards identifying and iterating on themes until agreement was reached.

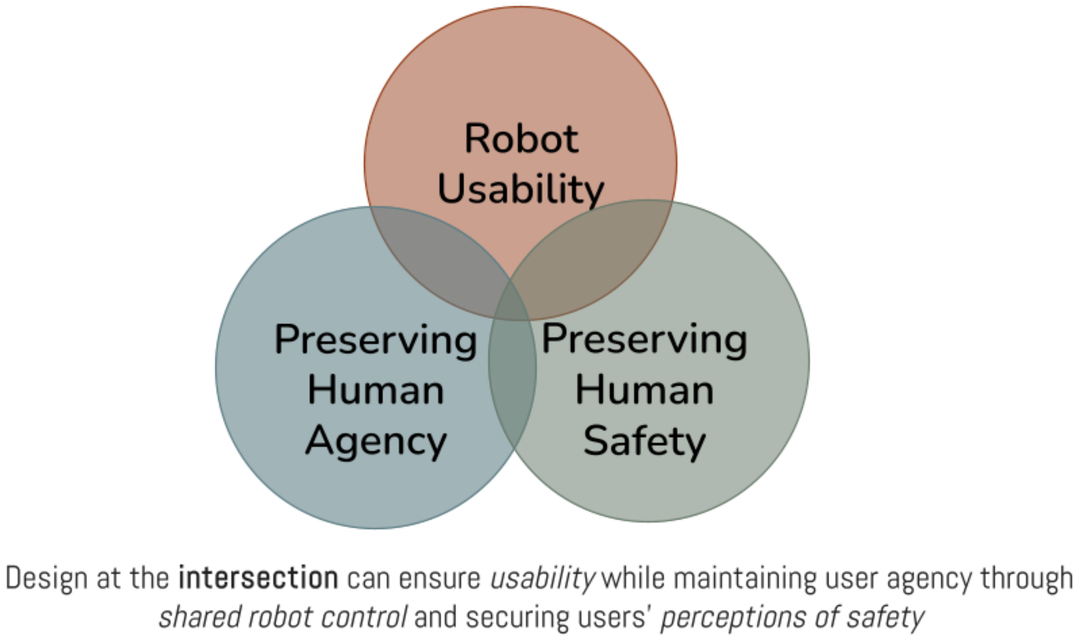


Figure 3.4: An illustration that demonstrates the inextricability between usability, user safety, and user agency during guide robot use.

3.7 Results

We identified three major themes (see Fig. 3.4): (1) usability, (2) human agency versus robot autonomy, and (3) safeguarding BLV users' perceived safety. While these themes are outlined separately, they are inextricable from each other and interrelated. For example, usability encompasses the general functions and capabilities that people wanted the robot to have. These functions and capabilities can, in turn, impact human agency, robot autonomy, and safety. Additionally, the balance between human agency and robot autonomy can affect safety and usability, and safety can also affect human agency and robot autonomy. Each of these three themes is further refined into sub-themes in the discussion below.

3.7.1 Usability

This section captures specific features that participants desired from guide robot systems, including how robots should perform specific actions, the environments in which they should be capable of performing these actions, and when they should perform them. These features can be identified at each point of interaction with the guide robot, i.e., the beginning, middle, and end of the interaction.

Requesting a Guide Robot Upon entering a guide robot's workspace, participants wanted to be able to request assistance from the robot in different ways. At the beginning of the feature identification phase, we told participants that one potential method of requesting the robot could be through using a smartphone application (e.g., [29, 251]) to summon the guide robot to their exact location. While participants generally supported the idea of summoning the robot via smartphone, they also offered alternative methods for rendezvousing with the robot, including summoning it by a phone call (for those who have trouble using smartphones) or being guided to it by a passerby.

Meeting a Guide Robot Several participants wanted a guide robot to greet the user and identify itself verbally. Additionally, participants described wanting a guide robot to repeat their requested destination before leaving for confirmation, particularly if it was requested via a smartphone app. Alternatively, other participants envisioned a system in which they would let the robot know their desired destination once they met it. For first time users, participants wanted the robot to give an overview of its capabilities and functions, as well as describe the tasks that the robot is capable of performing and assisting (e.g., [285]).

Initiating Physical Contact Participants wanted varying degrees of assistance with locating the robot handle. Some suggested that the robot handle provide an auditory cue to assist them in finding it. Furthermore, participants mentioned alternative ways of locating the handle for participants with hearing impairments, including P01 who mentioned that “for our deaf-blind friends, it would probably need to be something where the robot comes in personal contact with the person" (P01, female, age 43, guide dog & cane), signaling the need for a haptic option. Many participants desired a smartphone interface to give directions to the robot relative to them and wanted the robot to position itself close enough that they could find it (e.g., [251]). Some participants wanted the robot to detect and confirm whether a user made successful contact with the handle. Also, participants suggested having the robot face the direction in which it will start going towards their destination.

Navigating with a Guide Robot (1) Robot Motion in Tight Spaces: Building navigation includes traveling through open spaces as well as corridors and doorways with varied dimensions. Participants wanted varying degrees of mobility-related assistance, including with turning guidance. While some participants reported being able to infer turns from proprioceptive cues afforded by the angled suitcase handle of our guide robot, which they shared made turns more apparent, other participants wanted the robot to indicate an approaching turn and its direction verbally or with haptic feedback. In general, participants wanted to be able to open doors themselves. A few participants also wanted the robot to identify the type of doorway (e.g., revolving doors versus double doors versus single door) and which way the door opened so they would know what to expect. Some participants also expressed a desire for the robot to announce the width of a doorway so that they could move behind the robot without bumping the door frame. Finally, participants generally wanted guide robots to simply take them around obstacles, indicating that the robot's motion was a sufficient cue to indicate these actions. However, a few participants also wanted to know what the obstacle was, especially if it was a permanent feature versus something that might not be present later.

(2) Robot Motion and Navigating Around People: There was a lot of hesitation about dealing with crowds. P11 highlighted this common concern: “I can barely make it through crowds myself with the cane; it's pretty tough," (P11, female, age 39, guide dog & cane). The general consensus amongst participants was that guide robots should try to avoid crowds if possible, look for openings to navigate through people, or stop and wait for crowds of people to pass. Some participants wanted the robot to emit an audible cue to help clear the path for the guide robot without startling passersby [208]; others preferred to speak for themselves. Additionally, participants shared interest in guide robots having the ability to detect and guide users to the end of queues, similarly to previous work (e.g., [228]). Furthermore, some participants shared concerns about colliding with another human coming around a corner and wanting a guide robot to be aware of giving a human the right of way. Participants' reticence with respect to encountering crowds highlights the existing

challenges with social navigation, as many of them were unsure of how the robot should behave.

Guide Robot Providing Information During Navigation Several participants mentioned that they wanted a guide robot to announce locations of interest as they passed by them. The recommended locations included restrooms, information desks, elevators, amenities such as lounges with couches, water fountains, and places to eat. Participants also mentioned stairwells, hallway intersections, exit doors, and windows as building features of interest. P12 and P06, two of our LV participants, wanted information about changes in elevation, potential tripping hazards, and obstacles above eye level. While participants shared that they want to receive this information, they also shared concerns about receiving too much information. As a result, participants wanted control over the flow of information, such as by interrupting the stream of information and requesting more information from the robot. Finally, participants mentioned also being able to pre-select the amount of features and locations of interest to describe beforehand.

Participants desired information to be communicated through various sensory modalities. These included haptics, particularly using vibro-tactile cues for notifications or turn signals. Participants also recommended audio cues, including both speech and beeps or tones. Those who wanted the robot to provide audible information also wanted to control the volume either directly on the robot or through their smartphone. Most participants preferred to have an option to connect their headphones or hearing aids either directly to the robot or use their smartphone to receive audible information, especially in crowded spaces. Some participants expressed the desire for the robot to automatically adjust its volume to environmental changes, such as the presence of other people. Furthermore, participants noted that the design of cues in different modalities would have to be carefully considered. For example, the meanings of cues in certain sensory modalities could be unintuitive or confusing. P03 mentioned, "I guess haptics on the handle could indicate a lot of things" (P03, female, age 68, guide dog & cane). Thus, the information conveyed by a specific modality should be customizable so it is easily understood by the user. Additionally, an interface that enables customization can support accessibility. For example, P16, who has hearing impairment, expressed a preference for haptic notifications over audible ones.

Controlling a Guide Robot Many participants voiced strong preferences for how to control the robot. They desired buttons for speed control and for starting and stopping the robot, which they suggested to be placed on the robot's handle (in line with [165, 435]). A few participants also wanted to control robots through speech commands.

Several participants indicated strong preferences for interacting with robots through a smartphone. Participants' interest in customizing experiences seemed to influence these desires because they could use their smartphones to curate experiences, reduce learning curves (for people who were already comfortable using phones), and adapt the accessibility settings. Additionally, a smartphone interface would allow them to directly control the volume level or pair existing headphones or hearing aids, which are commonly Bluetooth-connected. Preference setting on smartphones could also support customization of which information was conveyed during navigation (e.g., locations of interest, building features, etc.).

In contrast to controlling the robot, participants also expressed the desire for some robot behaviors to be performed autonomously. As described previously, the participants wanted guide robots to sense the presence of others, both in order to detect crowds and to lower the volume of audio cues to not disturb other people: "I would want [the robot] to be sensitive to things that annoy other people." (P13, female, age 78, cane) Additionally, the participants wanted the robot to sense the position of the human user in order to navigate comfortably through narrow spaces like doorways (e.g., as in [296]).

Guide Robot Form Factors and features Some ideas from participants suggested that the form of a guide robot must complement the environment in which it functions. For example, P16 and P04 described a supermarket guide robot taking the form of a shopping cart (e.g., as in [227]). Similarly, some participants wanted guide robots to lead them through stairways, necessitating the ability to mount and descend stairs. Several common locations that participants wanted to use guide robots were airports, hospitals, and malls (e.g., [164, 166, 209]). These places have unique challenges for participants, including large open spaces and densely populated areas. Some participants desired to use these robots in unconventional places, such as a cruise ship and baseball stadiums, which also include stairways and openings. Furthermore, a few participants identified challenges with holding onto a guide robot and having free hands to carry or use objects, such as steering a shopping cart, carrying a suitcase, or using a white cane, which some participants preferred to use in conjunction with the guide robot. This would also be a factor if using a smartphone application with the robot.

Moreover, some participants desired standardization of guide robots and their features. For example, P01 was frustrated about how unrealistic the idea of guide robots arriving at her location without policy-level changes that enforce standards related to automated assistance within public buildings (e.g. [317]).

> "[I]t would have to be sort of a standardized thing where [...] [public places] all have the same robot and [...] [an] app on the smartphone that all blind people use."

Therefore, although guide robots can have contextually-dependent form factors, it is critical to consider how standards can improve user expectations and support the usability of guide robots across public settings.

Ending Contact with a Guide Robot (1) Notification of Approaching Destination: Participants reached consensus on wanting the robot to issue a notification similar to a GPS app when they were nearing their desired destination. Some participants wanted additional information about the state of the area, including information about the social density of their destination. Some participants wanted the robot to prompt them about whether they wanted to end the interaction before leaving them at their destination.

(2) Continued Presence of Guide Robot: Several participants were comfortable with the robot departing upon finding their destination in the building. For example, P08 shared that they would be comfortable having the robot leave once they found their desired seat in a theater and would request another robot when ready to leave. However, a few participants were interested in continued presence of the robot, especially when the person was to remain in the building for long periods of time. P16 said robots should accompany the user until they leave the building and have the ability to take the user back to their starting point (e.g., homing feature [229]).

(3) Guide Robot Providing Transitioning Information: Participants generally wanted robots to provide information that assisted them in easily transitioning to their destination, locating their destination, and preparing for the next leg of journey. For example, one of P14's

imagined use cases was in a transit station; thus, he wanted the robot to leave him near a wall as an anchor: "Take me to nearest wall, or something to touch, [a] bench, [or a] receptionist area" (P14, male, age 51, guide dog & cane). Several participants wanted directions to the next place where they would travel, including the estimated time of arrival for public transport. In later sections, we showcase the importance that these features and functionality express participants' desires for control over the robot behavior and influence their perceptions of safety while using the guide robots.

3.7.2 Human Agency versus Robot Autonomy

As discussed in the previous section, participants repeatedly expressed desires to exert control over the robot's behavior. In this section, we highlight their rationale and the implications. There were several factors that influenced participants' desires for independence, which shaped how much control they expressed wanting over the robot's behaviors and decisions. Participants shared specific instances in which they had to rely on other people for assistance and strong desires to navigate without depending on others. They also agreed that there are contexts in which the robot could operate independently without their input, such as environments that are unfamiliar to the participant. Furthermore, access to information was critical to safeguarding independence. Several participants discussed that access to information about their surroundings ensures adequate knowledge to make decisions. For example, participants wanted the option to know about features of interest along the way for opportunistic stops along the route. Additionally, some participants wanted to have control over a guide robot's chosen path. P16 shared her desire for "a mechanism by which the user can be a little more autonomous [... and] suggest the next left." P02 echoed this by expressing her desire to control the guide robot similar to how she would command her guide dog, "You could tell it right and in" (P02, female, age 65, guide dog & cane). While these strong desires for control were commonly espoused by guide dog users, control schemes that favor shared robot control could positively impact a BLV user's overall sense of independence and agency.

3.7.3 Safeguarding Users' Perceived Safety

As mentioned, a common theme centered on how guide robots' behaviors and available functions have implications for ensuring the human user's continued perceptions of safety in public settings. Similar to the previous section, ideas of control also hinged on access to information. We previously noted that participants desired varying amounts of information from a guide robot depending on their familiarity with a location or their comfort navigating in new places. Thus, access to information is important in preserving perceived safety during navigation. Additionally, some participants expressed strong desires to use guide robots in conjunction with other mobility aids. For example, P16 wanted additional tactile information from a cane, "I always have my cane because I'm hard of hearing. I need all the tactile information I can get." Other participants did not espouse these sentiments due to reservations about having too many things to hold or due to trust in the robot. The desire (or lack thereof) for the continued use of mobility aids could be tied to preferences about robot path planning, particularly near obstacles, and how close users want to be to them. Multiple participants shared their understanding of how robot behaviors and decisions influenced their perceptions of safety and trust in the system. While over time, repeatable demonstration in the system's capacity to safely transport them to their destination resulted in growing feelings of trust, some participants still felt skeptical (P01: "What I disliked was that I didn't understand how [the robot] worked. In real life, I'm never going to trust a navigation device that I don't have the faintest clue how it works, where we're going, what we're doing. I did not enjoy that."). This desire for robot transparency on capabilities and decision processes supports participants' previously stated desires for a system overview at the beginning of interaction.

Some participants shared significant concerns over the robot sensing and responding to emergencies and other major changes to an environment. P15 reflected on her experience responding to a fire in her office building. She expressed strong desires for a guide robot's ability to alter the user's desired path plan to the nearest emergency exit in response to such emergencies. Additionally, P16 shared that since she has hearing impairment, she wanted haptic notifications of emergencies on the handle since she felt it would be most accessible and easily interpretable to her. P05 noted that some environments, such as airports where Transportation Security Administration (TSA) agents are present, may be places where the volume of environmental information should not be occluded by the volume of robot speech. Thus, a guide robot should sense and respond to changes in the environment, including social presence. Participants also wanted the ability to request human assistance while using the robot, highlighting that users do not want the robot to be their sole source of assistance.

3.8 Discussion

Our work highlights several important findings necessary to designing robotic mobility aids and systems that can improve the independence of people with visual impairments. While some of these findings are novel, many of them support prior findings in the space of guide robots [29, 227, 228, 229, 251, 285, 296]. Still, our work underscores the importance of replication in disability-centered studies, particularly in the assistive domain. Furthermore, our work further justifies the technical decisions and guidelines utilized in prior work.

3.8.1 Context-dependent Guide Robot: Behaviors and Form Factors

Our findings suggest that participants guide robots with context-dependent behaviors and form factors. Several participants articulated that guide robot behaviors should conform to social expectations, similar to prior work [29]. However, these definitions varied according to individual preferences and experiences of participants. For example, participants who had experience with guide dogs noted that guide dogs are not capable of speaking. Therefore, they did not want guide robots to speak for them, instead desiring to utter socially appropriate speech (e.g. “excuse me”) for themselves [29]. Furthermore, participants mentioned using headphones or hearing aids to receive communication from the robot. In such cases, they would prefer the robot speak at normal volumes. Otherwise, they would prefer the robot be able to automatically modulate its speaking volume based on its environmental awareness.

In novel findings, we discovered that participants’ preferences for the form factors of guide robots varied on the use context. In contrast to prior work, which suggested that BLV users had little consideration for the appearance of the robot [181], some participants wanted the guide robots to have form factors that conformed to the environment, for example having a guide robot in the form of a shopping cart within a grocery store. The appearance of the robot, in this case, suggested its affordances aligning with the use context. Nevertheless, some participants desired that there be guide robot standards across public settings to ensure improved usability among BLV users. Finally, we found that participants stressed the importance of the robot's motion in crowded spaces. They insisted that the robot should adapt to move slower, avoid crowds all together, and be mindful of turn-taking conventions.

3.8.2 Implications of Scenario-Based Design

In contrast to previous studies [29, 229], our guide robot design exploration was situated within the context of diverse scenarios and environments, allowing us to identify several requirements without being physically present in those locations. Furthermore, idea generation was grounded in participants' lived experiences and carried the richness of those experiences with them. Therefore, our findings were also not limited to the indoor environments seen in past studies, which were primarily university buildings [229]. Our participants generated ideas situated in situations they had previously been in; for example, one participant's scenario involved a cruise ship. These diverse scenarios surfaced the unique challenges BLV travelers face in different environments, helping to elicit novel design requirements for guide robots.

However, since participants experienced a wheeled guide robot in the first part of the study, this may have limited their imagination with respect to whether guide robots could assist them up the stairs. However, through the SBD approach, participants were encouraged to ideate beyond their experience, which enabled participants to generate ideas unconstrained by technical limitations. Furthermore, SBD allows participants to provide ideas about safety-critical encounters without placing them in any physical danger. Still, the lack of contextual factors experienced when within a space means we may have missed additional considerations. In future work, it would be beneficial to test ideas on physical systems to allow participants to provide real-time feedback. Moreover, the use of simulations can allow for immersive, real-time prototyping that also enables testing of safety-critical scenarios.

3.8.3 Quantifying Participant Comfort and Perceived Safety

Several key challenges in the evaluation of user preferences for this application have arisen in the course of the study, particularly when it comes to evaluating users' perception of safety. First, questionnaire [357] results are not sensitive to users' expressed preferences. Many participants have reported low scores to feelings of anxiety and high scores to feelings of comfort/usability after each trial with the robot. However, both immediately after the trials and when asked follow-up questions during the semi-structured interviews, they also reflect on non-ideal behaviors of the robot such as bringing them too close to obstacles or causing them to maneuver awkwardly. This presents contradictory accounts of how users perceive their safety with the robot. Guide dog and cane-only users also had different preferences for the behaviors of guide robots. Guide dog users tended to find the robot easier to follow, often based on their experiences with their dogs; cane-only users were more likely to find it awkward or unintuitive.

Furthermore, while we aimed to perform post-hoc affect analysis using video footage, the modalities used to estimate affect in BLV are uncertain. For example, while facial expression is a common modality used to measure affect, there is evidence that suggests that having visual experiences impacts the production of facial expressions in BLV people, causing variability, intensity, and control in the facial expressions of BLV people [405]. Prior work suggests that biosignals offer promise for navigation-specific tasks [348]. Prosody is also a potential modality for estimating affect [71] that may be useful for our application [267].

3.8.4 Limitations: Critical Reflections on Engagements with People with Visual Disabilities

The first major limitation was considerations for the lived experiences of low vision people shape how guide robots behave and the interactions that they support. Although this work centered on providing design recommendations for robotic mobility aids for pBLV, it is worthwhile to critically reflect on the methodologies of this work, the design outcomes, and the importance of expanding beyond single identifiers with respect to disability to ensure that participation is truly equitable.

Through these scenario-based engagements, I neglected to prioritize the diversity in human experience. That is, I engaged with people as if their (dis)abilities were the sum total of their lived experiences, which was reductionist [393, 394]. That is, the focus on an individual applied to disability-related technology research [431], which ignores how forms of oppression intersect [90]. For example, Black Americans with disabilities have additional access barriers to assistive technologies [413] resulting from social inequities driving public policy and financing that expands disparate access. These notions descend from legal scholars and Critical Race theorists, Crenshaw and her contemporaries, who introduce the concept of "intersectionality", an analytical framework to understand the intersections of multiple oppressions due to the social identities of a person (e.g., race, gender, class, etc) [97].

In this work, the degree to which I engaged in lived experiences of PwDs did not cross their single identifier as a person with a visual disability, a common fault in disability-related research. Although disability-related information is informative and undoubtedly important, it cannot be all. We did not compile other sociodemographic information other than disability information. But the experiences of PwDs, and in this case, pBLV, are impacted by identities external to just their disability/disabilities For example, Bennett and colleagues – researchers in critical lenses in HCI and design research – write about the intersections of visual disability, race, gender [43]:

> "Race is a sociomaterial system of categorizing people based on factors including, but not limited to, ancestry, culture, physical features, social and behavioral qualities, and self-identification" [43].

They go on to detail how pBLV are primed to identify the identities of others through non-visual means. Furthermore, they call into focus the experiences of multiply marginalized pBLVs and their experiences with racialized exclusion. These perspectives within disability-related technology research underscore that PwDs' lived experiences are informed by their experiences beyond simply the disability-related categories researchers use. For example, the consideration of how people with visual disabilities may perceive the use of a robot in a public setting may be influenced by their experiences with hyper-surveillance. Carrie Sandahl [350], Disability Arts and Humanities scholar, wrote about Lynn Manning, a Black American former Paralympian, playwright, poet and actor who was Blind:

> "Like black men, people with disabilities experience the paradox of being at once hypervisible and invisible, but with a difference. He is now caught within a new network of gazes; he is now under constant medical surveillance, not only by medical and social service professionals, but even by members of his own family."

It is crucial to engage with PwDs — their diversity and lived experiences beyond just centering their (dis)ability; this is a salient way of engaging, knowing, and sharing in discussion about the technological futures they envision. Considering other social identities is integral to understanding PwDs' lived experiences – a lesson I aim to carry into subsequent research as both descriptive and analytical factors when co-designing with PwDs.

3.9 Summary

In this work, we conducted a two-phase user study aimed at identifying how path-related and other guide robot features impact a BLV user's sense of comfort and orientation. We highlighted important considerations for designing future robotic mobility aids that can increase BLV people's sense of independence as they navigate the world.

Service Robot for Assistive Navigation: Design Takeaways

1. Enable multiple ways for BLV end-users to request or rendezvous with a robot, including through smartphone app, phone call, or by sighted guide.
2. Enable shared robot autonomy paradigms and opportunities for direct user control over behavioral execution of guide robots.
3. Guide robot form factors should be compatible with BLV end-users' existing mobility aids and devices.
4. Additionally, guide robot form factors should be context-dependent; for example, consider augmenting utilitarian objects with guide robot capabilities (e.g. guide robot/shopping cart integration for assistive navigation in supermarkets).

5. For social navigation, guide robots should avoid crowds, where feasible. However, some BLV end-users are willing to perform verbal social behaviors (e.g., saying excuse me).
6. Guide robots should provide information to BLV end-users. The amount, frequency, and type of information should be customizable by BLV end-users.
7. Guide robots should be capable of multi-modal communication. Robot interfaces should be interoperable with personal listening devices (e.g. headphones or hearing aids) for discrete communication and modulate volume levels to minimize social disturbance, unless a user does not have personal listening devices.

Methodological Takeaways

1. SBD simulated verbal dialogues is an accessible modality for design ideation communication and iteration.
2. Mutual learning occurred through encountering a guide robot prototype, which functioned as a technological probe. However, experiencing a probe before considering one's lived experiences with navigation, including challenges and alternative possibilities, may bias and limit ideation.
3. Co-constructed scenarios function as "soft prototypes" [73] that are imbued with the experiential knowledge of PwDs.

Part III

Designing Service Robots with Diverse Disabled Adults

4 Co-designing Delivery Robots with Diverse Disabled Adults

Part of this work is featured in *Boadi-Agyemang, A., Moharana, S., Bennett, C. L., Carter, E. J., Carrington, P., & Steinfeld, A. (2026). Pluriversal Approach to Co-designing Delivery Robots with People with Disabilities. In Proceedings of the 21st ACM/IEEE International Conference on Human-Robot Interaction.* [50]

On-demand, last-mile delivery – the transportation of goods from a local distribution center to the customer's door within a specified time window – is used by people with disabilities (PwDs) for a variety of reasons. While delivery robots have potential in this space, they often widen disparities in access for PwDs. Inspired by the concept of pluriversality, which embraces the diversity of worldviews, we facilitated participatory design workshops with PwDs to co-design accessible and equitable delivery robots. Our findings support the importance of delivery robots with varied form factors that are robust and customizable to support diverse PwDs and their respective needs and preferences. We also provide broader considerations for automation in delivery ecosystems.

4.1 Introduction

On-demand, last-mile delivery (OD/LMD) - transportation of goods from a business to a customer's door during a time window specified by the customer – is used by people with disabilities (PwDs) for various reasons. For some PwDs, delivery offers convenience.

However, for others whose mobility is curtailed by limited accessible transportation options [246], OD/LMD represents a lifeline. Autonomous delivery robots (ADRs), or simply delivery robots, is an umbrella term [191] for systems that have the potential to bridge this gap. Companies tout several advantages of delivery robots for expanding the supply chain, including increases in efficiency; reductions in delivery times; the advancement of sustainability goals by championing 'clean', autonomous alternatives; and even the promotion of 'equity goals' by 'providing automation to more neighborhoods' [305]. Unfortunately, these autonomous systems have also created tension and barriers for PWDs (e.g. [38]). In the U.S. alone, examples of negative interactions with ADRs include a mobility scooter user who was repeatedly blocked from traveling on the sidewalk [100], a wheelchair user who could not use a curb cut that was blocked by a stuck robot [9], and a guide dog user who encountered problems with a robot [155]. These events have motivated new designs to ensure accessible interactions with PwDs [38, 171, 172]. These efforts primarily focused on people with mobility disabilities (PwMDs), necessitating input from other groups of PwDs. For example, delivery robots are often unable to detect the white canes of people who are blind or have low vision (pBLVs), decreasing safety. Still, these works centered on bystander interactions; one major ADR company reports that around 20% of their UK customers are PwDs [397]. Thus, it is imperative that ADRs are accessible for PwDs who are bystanders <u>and</u> customers. However, PwDs are diverse populations with varied access preferences and needs [393], making universal solutions difficult.

Pluriversality [128, 129, 298, 399] is a concept concerned with embracing plural universes that result from the diversity of humanity; it stands in contrast to universality, which typically seeks a single design that works for as many users as possible [287]. Pluriversal designers assert that there cannot be one universal solution and seek technologies that 'embrace ontological and epistemological diversity by being co-designed, co-produced and co-owned by the inhabitants of the socio-cultural territory in which they are embedded' [142, 167, 408]. We used a pluriversal approach [406] to participatory design workshops [281] with a variety of participants and sought potential solutions to answer the following research questions:

- **RQ1**: How can delivery robots be (re)designed to ensure that they are *accessible* and support a diverse range of PwDs with different needs?

To this end, we must interrogate who we are designing for and what their needs are. There is a dearth of research on motivations [333] and challenges facing PwDs regarding OD/LMD (e.g. [114, 295]). Furthermore, in the U.S., the poverty rate for PwDs is 2-3x more than that of people without disabilities [61]. Within the category of PwDs, subgroups are more likely to live in poverty, including people who are Black or Hispanic. Thus, we also consider:

- **RQ2**: What are the experiences, including motivation and challenges, that local PwDs face when receiving OD/LMD?
- **RQ3**: What are the desires of PwDs, who face intersecting social marginalization, for *equitable* delivery robots?

We recruited PwDs from different social backgrounds in our local community. Over two months, participants were invited to engage in two phases: an initial workshop aimed at capturing their experiences and perspectives on existing last-mile delivery services and robots toward (re)designing future delivery robots; and participatory prototyping workshops in which participants iterated on co-designs through in-person sessions and remote diary studies.

The contributions of this chapter are twofold: 1) Our work surfaced varied design ideas for delivery robots – different form factors, capabilities, features, and interaction modalities – to ensure that OD/LMD is accessible for a variety of PwDs' households; and 2) community-informed considerations that roboticists and designers should incorporate when designing ADRs.

4.2 Related Work

4.2.1 Autonomous delivery for PwDs

Many PwDs rely on public transportation, leading to challenges due to lack of adequate accessible options (e.g., [246, 388]). Thus, many PwDs use OD/LMD to get resources [114, 295], increasing exposure to ADRs. Current models include personal delivery devices using wheeled and legged robots that operate on the sidewalk and bike lanes [305], often referred to as sidewalk delivery robots (SDRs; e.g., Starship, KiwiBot, and Serve). Some use a mothership autonomous vehicle (AV) to transport SDRs to their delivery locations [191]. Similarly, some manufacturers are exploring autonomous aerial robots or drones (e.g. Amazon Prime Air [159]).

Most design research on ADRs has involved non-disabled people [18, 200, 221, 371, 417, 432], particularly in sidewalk interactions. However, sidewalk interactions with PwDs can be more challenging to navigate and have worse outcomes than those with a person who can easily detect and walk around a robot. Less work has involved PwDs to understand their perceptions and engage them in participatory efforts to ensure these interactions are accessible [171, 172, 437]. Recent work has begun focusing on sidewalk interactions between robots that operate in public settings and PwDs [38, 171, 172].

4.2.2 Pluriversal Design in HRI

Disability-related technology [431] seldom interrogates the social and material conditions of PwDs beyond their individual disability identifiers [393]. For example, PwDs in the U.S. are more likely to live in poverty [61] and experience food insecurity [68]. Within this category, subgroups of PwDs are more likely to live in poverty, including people who are Black or Hispanic and people with lower educational attainment [61]. However, in HCI and HRI, participatory design workshops often hinge on 'blue sky' ideation – imagination unbridled by social or economic constraints – which further marginalizes already under-served communities [175]. Previous work at the intersection of disability and racial, ethnic, and gender identity have illustrated how access needs for PwDs with intersecting social marginalization can be complex [43, 176]; however, these discourses seldom shift how participatory workshops are conducted in HRI (e.g. [427, 438]). Pluriversality arose from methodologies of decolonial design [10, 13, 14, 16, 206, 236, 243, 399], which has been been used in other areas of HCI research to ensure technologies that are culturally and socially appropriate [21, 27]; these works demonstrate pluriversal approaches can enable the design of technology for the equitable interactions with under-served communities.

4.3 Method

Pluriversal design methodologies focus on fostering future possibilities for the diversity of humanity [298] and are guided by several design principles [406]. These are **(PD1)** using participatory approaches; **(PD2)** encouraging physical encounters (and creating 'safe' meeting environments to encourage discourse, which involves disagreement); **(PD3)** fostering alternative possibilities/solutions; **(PD4)** supporting connections between past and future through visual thinking and bodily expressions; and **(PD5)** practicing 'radical empathy'; **(PD6)** use of pluriversal narratives (to avoid distilling the findings). We aimed to implement these principles in our work.

4.3.1 Participants & Group Compositions

We recruited 14 local participants (9 women, 5 men) who were between 31 and 75 years old ($\bar{x} = 55$, SD = 14.5; Table 4.1) via outreach to community centers, community email lists, local disability groups, and word of mouth. Although participants had varied disability experiences, demographic forms and participant statements during sessions indicated a predominance of visual, hearing, and mobility disabilities. Some participants specified using corrective technologies (i.e., glasses) while others did not (i.e. 'unspecified'). They reported varied employment and income statuses.

Table 4.1: Delivery Robot Participant Demographics Overview

Pseudonym	Age Range*	Gender	Mobility Disability	Visual Disability	Additional Disabilities	Race/Ethnicity	Employment Status	Income Status	W1 Groups	W2 Groups
Pittsburghgirl	50–60	F	Arthritis	—	'Profoundly deaf'	White/Hispanic	Full-time	Extremely-to-Very Low	Group 1	Group A
Kassandra	30–40	F	AMC[1]; UED[2]; Arthritis	—	—	White	Part-time	Extremely-to-Very Low	Group 4	—
LGP	30–40	F	SB[3]	—	—	Asian	Volunteer	Extremely Low	Group 4	—
Mushy	55–65	F	Arthritis; UED[2]	Unspecified	Hearing Disability	Black/African American	N/A	Extremely-to-Very Low	Group 3	—
In-Remission-Man	65–75	M	Arthritis	—	Hearing Disability	Multiracial	Retired	Extremely Low	Group 3	—
Gabriel	65–75	F	Arthritis	Blind	—	White	Retired	High	Group 1	Group A
iamcool	50–60	M	—	Blind	—	Asian	Full-time	Low/Moderate	Group 8**	Group C
Effdi Jay Tee	40–50	F	—	Blind	Deaf	White/Hispanic	Unemployed	Extremely Low	Group 2	—
Abraham	30–40	M	—	Low Vision	—	White	Unemployed	N/A	Group 2	Group A
R.J.	60–70	M	—	Blind	Hearing Disability	White	Retired	Extremely-to-Very Low	Group 2	Group A
sleepsong	40–50	F	Arthritis; MS[4]	—	—	White	SSDI†	Extremely Low	Group 6**	Group C
Astrid	60–70	F	Arthritis	—	Hearing Disability	White	Part-time	Extremely Low	Group 7**	Group B
Mickey	70–80	M	—	Blind	—	White	Retired	High	Group 5	Group B
Mocha	60–70	F	Arthritis; UED[2]	Blind	Hearing Disability	White	Retired	Extremely-to-Very Low	Group 5	Group B

[1] AMC: Arthrogryposis Multiplex Congenita; [2] UED: Upper Extremity Disability; [3] SB: Spina Bifida; [4] MS: Multiple Sclerosis; † SSDI: Social Security Disability Insurance, which limits employment; * For anonymization, we provide decade ranges instead of exact age; ** Solo workshop sessions.

4.3.2 Methods, Study Locations & Procedure

We used a two-phase participatory design approach [281] **(PD1)**, which included an in-person **initial workshop** and **iterative participatory prototyping workshops**. All workshops were facilitated by the same two researchers. This study procedure was approved by our Institutional Review Board (IRB) and participants were compensated for their time. This work was conducted in Pittsburgh, a medium-sized U.S. city, over a two-month period in 2025. Participants selected a minimum of three accessible locations. Most of the selections were private meeting rooms in public libraries [125], offered because they are neutral democratic spaces **(PD2)**; only two workshops were held on our institution's campus. We used participant availability information to organize groups of between two to four participants. In some cases, cancellations resulted in solo sessions (see Table 4.1). Participants completed consent and demographic forms prior to in-person sessions, either via a secure web form or paper. Access needs were also obtained in advance and participants were asked to share relevant access needs during group sessions to ensure patience and empathy among group members **(PD5)**. Participants selected their own pseudonyms to allow control over how they were named and referenced in the data [231]. Income status categories are based on the number of people in a household [304].

Initial Workshop (W1)

This phase focused on understanding the experiences of our participants with OD/LMD services and technologies **(RQ2)**. We wanted to understand how delivery robots and OD/LMD technologies could be (re)imagined and (re)designed **(PD4)** to ensure they are accessible and equitable for diverse groups of PwDs **(RQ3)**. There were three sessions (see Fig 4.1): 1) *Focus group*. During this session, participants focused on their motivations for using OD/LMD, challenges they face, whether their experiences are impacted by their social identities (e.g., disability, race, geographic location, etc.), and their perceptions of OD/LMD technologies. At the end of this session, participants co-constructed a list of priorities for the future of accessible OD/LMD. Solo sessions were operated similarly to semi-structured interviews. 2) *Technology demonstration*. During this session, participants were introduced to delivery robots through videos with audio descriptions and tactile mock-ups. The videos featured Starship's wheeled sidewalk delivery robot (SDR) [396] and Agility Robotics' humanoid robot [341]. These two robots were selected to provide varied examples that included common, commercially available delivery robots (SDRs) as well as futuristic options (humanoids). 3) *Ideation Activity*. In this final session, participants engaged in various activities to help inform ideas and ensure that they were grounded in their experiences with OD/LMD. The first activity, inspired by somaesthetic reflection and articulation [239], called participants to reflect and express a detailed experience with OD/LMD; next, we provided a variety of modalities to support diverse preferences for communicating design ideas **(PD4)**, including verbally communicated and written scenarios [74, 347] and storytelling [42, 379]. We also offered 'generative toolkits' [352] that included materials for tactile ideation, such as Legos and other craft materials [291, 395], and audio recorders [281]. We also allowed participants to document ideas on their smartphones, which are common access technologies for many pBLVs (e.g. [363]). This workshop took 3.5 hours.

Figure 4.1: Initial workshop, from left to right: list of priorities from focus groups, technology demonstrations, and initial ideation session.

Participatory Prototyping Workshop (W2)

We offered the option to also participate in up to three in-person iterative prototyping workshops (see Fig. 4.2). These iterated ideas that emerged in W1 **(RQ1)**. We incorporated a *design-led approach* to co-designing [352] accessible and equitable delivery robots with our participants/co-designers. W2 sessions involved a range of collaborative activities, such as engagements with a co-designed SDR mock-up that enabled participants to iterate on their ideas from W1. They also included high- and low-tech materials, such as technology probes (e.g., text-to-sign language software, sound buttons, audio cues) and the generative toolkits used in W1. After each workshop, participants engaged in a diary study for 7 days. This allowed participants to reflect on co-designs and suggest improvements for future workshops. While this phase focused on improving delivery robots, we allowed participants to envision alternate solutions to OD/LMD challenges **(PD3)**.

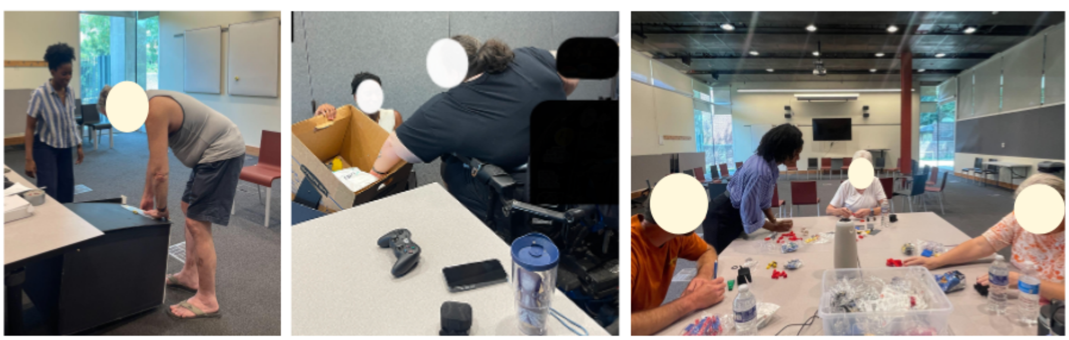


Figure 4.2: Co-design workshops: Participants engaging with co-design mock-up and creating physical mock-ups using Legos.

4.3.3 Qualitative Analysis

Qualitative data was analyzed deductively and inductively [132] throughout the study. Deductive codes were identified from prior work on delivery robots [171, 172, 371]. Research findings were written as pluriversal narratives **(PD6)**.

4.4 Findings

We organized our findings around the experiences of PwDs with OD/LMD **(RQ2)** (see 4.4.1), followed by their desire for more accessible **(RQ1)** and equitable **(RQ3)** delivery robots (see 4.4.2-4.4.7).

4.4.1 Delivery Experiences of PwDs

Motivations

We identified several novel delivery motivations for PwDs. While these motivations pervaded all workshops, they were most prominently stated in W1. Our disabled participants had several overlapping motivations for using OD/LMD.

1) Inaccessible Infrastructure and Disability-Related Access. Several participants cited inaccessible infrastructure, their disability, and the lack of accommodations in physical stores as motivation for using OD/LMD. For example, iamcool and Mocha, guide dog users who live alone, reported inaccessible transportation; Mocha, who also lives in a high-rise apartment, also reported difficulties with her physical mobility. Astrid lives alone and described her symptoms of vasovagal syncope as including fainting, which impacts her mobility and requires seating. Thus, in-person shopping and carrying bags on the bus were infeasible and resulted in greater reliance on OD/LMD. Kassandra lives with her grandmother but requires more physical assistance than her grandmother can provide; furthermore, limited public transportation or caregiver assistance options on weekends led her to rely on deliveries for some items. Gabriel lives with her husband, but used OD/LMD because she wanted to shop independently despite limited options for human assistance during in-person shopping.

2) Survival. While related to the previous motivation, some participants commented on using OD/LMD as a lifeline. Effdi is Deaf-Blind and uses a white cane. She emphatically shared that delivery for her is about “needing life-sustaining services” and that it is “always [for] survival”, citing inaccessible transportation options as a significant barrier.

3) Interdependent access. A few participants reported that OD/LMD provided opportunities for communal access to resources. For example, Mushy commented on using delivery to purchase “snacks for [her] grandkids.” Pittsburghgirl uses OD/LMD due to her dual roles as a caregiver. She is the primary caretaker of her two children, with whom she lives in a “food desert” (a neighborhood with limited grocery options [114]). For her, OD/LMD creates immediate access to resources, such as pharmacies and grocery stores. She also uses OD/LMD for supplies at her job as a geriatric nurse.

4) Independence. Several participants had empowering or positive motivations for using OD/LMD. Both participants who live alone (including LGP, a power wheelchair user, and iamcool) and those who live with family members (Gabriel and Kassandra) noted independence as a motivation for using OD/LMD.

5) Luxury and Comfort. sleepsong is a “local disability advocate” who uses a power wheelchair. She typically orders food, for which her motivations include “comfort” and familiarity – citing using delivery during times of physical exhaustion, chronic pain, and emotional duress. Moreover, Mushy and In-Remission-Man echoed ideas of OD/LMD as a luxury (e.g., to get themselves or their community something nice), and that they only use it when they have enough money.

6) Convenience, Ease, and reliability. Abraham and R.J. both live alone. R.J. uses a white cane and wears hearing-aids; and Abraham is low-vision. Both cited using delivery for convenience: Abraham having grocery stores in walking distance, and R.J. feeling comfortable using public transit to commute to his local stores. Moreover, LGP, Kassandra, Mickey, Astrid, and sleepsong also mentioned that they used OD/LMD for its reliability, convenience, and ease. Finally, Mickey, who uses a white cane and lives with his spouse in a private home, also cited the "efficiency" of OD/LMD, especially since his spouse gave up driving due to aging.

Challenges

For PwDs, the failures of delivery persons to follow delivery instructions has adverse effects on their ability to get resources in a timely manner. Although participants cited issues with the *ordering* step of OD / LMD (e.g., digital accessibility), we focused here on the "last steps" [338], namely issues with coordination of drop-off, performance of drop-off, and post-delivery.

1) Coordination of drop-off. For several PwDs, timing delays without notification are detrimental. For Kassandra, timing causes **inconvenience when physical assistance is needed** to retrieve items: "I have to do things on a certain schedule because I depend on someone else to take care of me." In addition, Mushy, who has a mobility disability, mentioned having to rush down when there are erroneous delivery notifications due to fears that her packages could be stolen; **theft concerns** were shared by In-Remission-Man, who often orders things to his brother's home instead of his own for security. Furthermore, participants reported that delivery drivers were unable to communicate through **accessible modalities**. Pittsburghgirl, who is profoundly deaf, noted that drivers tended to call despite her communicated access needs to text. Finally, some participants noted that experiences vary depending on the person delivering items. For example, LGP commented: "the different drivers that come [...] change the way things are delivered and the communication or lack thereof with me."

2) Drop-off. Drop-off issues depend on whether the delivery is attended (the recipient meets the delivery person) or unattended (the package is left at a designated spot) [338]. For pBLV customers, failures by **attended** delivery people to meet in an exact location can pose unique challenges; for example, Effdi and R.J. cited physical safety concerns with approaching an incorrect vehicle. Abraham, who is low vision, cited challenges with identifying drivers who assume he can see them. Moreover, these interpersonal interactions can result in discriminatory encounters: R.J. described **ableism** by delivery people who tended to ignore him – a sentiment with which Effdi and Abraham agreed. Participants also cited failures by delivery people, who can notify them either through designated communication channels (e.g., apps, texts, calls) or via intercoms, to do so upon package arrival. iamcool also cited language barriers: "drivers don't always speak English well, so when I need to ask questions [..] Sometimes [...] I don't get the answers."

As identified in prior work [242, 295], our BLV participants reported difficulties finding and identifying **unattended** packages that were not placed in the *specified* or *designated* delivery locations. Incorrect locations can be **physically inaccessible**. Kassandra shared that delivery people do not read instructions that specify a closer, more accessible location; instead, they tend to leave items in her inaccessible mailbox. Several participants noted that incorrectly placed items can cause **bodily harm** by being tripping hazards. Furthermore, Effdi and iamcool added that difficulties in locating misplaced items are exacerbated by inaccessibly labeled packages [242].

3) Post-delivery. Participants discussed a range of post-delivery issues, such as incorrect and poor quality items, problems with proof of delivery, and inaccessible customer support to correct problems. For many PwDs, issues with the earlier "last steps" of delivery **forces them to depend on non-disabled people** [242]; however, most of our participants live alone, reducing opportunities for assistance. LGP noted that while some delivery people are patient to help her verify her items prior to departing, this varies significantly. For several participants, opportunities for post-delivery support were fraught and tended to be biased toward inaccessible mediums. iamcool, who is blind, cited challenges with customer support asking, "Can you find somebody to help you? [...] send a picture of this" noting "its not as easy as they think"; this reflects a **bias towards visual proof** to resolve delivery issues. Kassandra, who has limited upper extremity mobility, noted that taking pictures is difficult and requires a specialized setup, which she does not have at home. In general, the performance of delivery varied by the delivery person and perceived differences in labor practices that prioritize expediency. Many participants were empathetic about these circumstances facing delivery people; however, their amount of consideration for these extenuating factors also depended on their motivations for delivery (see 4.4.1).

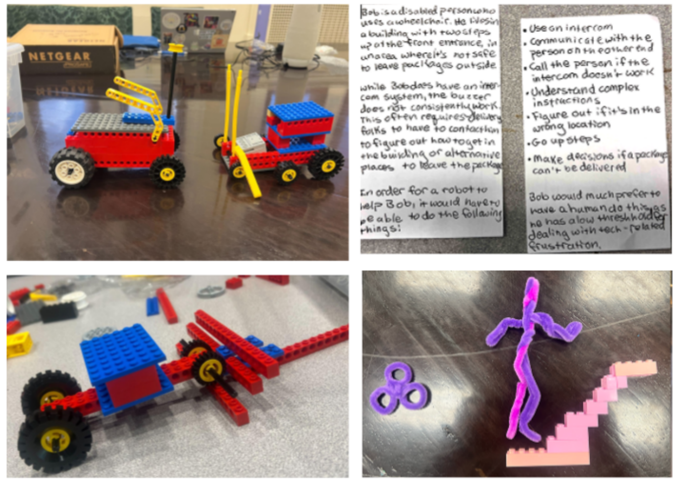


Figure 4.3: Design artifacts from pluriversal co-design: Lego mock-ups, counter-story. The counter-story reflects design refusal with text "Bob is disabled person who uses wheelchair" and "Bob would much prefer to have a human do [delivery]." A lego mock-up proceeding up stairs. A craft mock-up of humanoid robot proceeding up lego stairs next to a craft mock-up of a tri-wheels

4.4.2 Accessible Communication

Communication is imperative for the "last-few-steps" [338] of delivery. These include coordination, drop-off, and post-delivery, which necessitate timely and accessible communication through notifications delivered by text, call, or app.

1) Communication To Delivery Robots. Participants in the workshops showed preferences for various ways of communicating with delivery robots. **App-based interfaces** were a common option that several participants suggested. Communication through an app on their smartphone was preferential for some participants due to accessibility, particularly for people with hearing and visual disabilities. Also, several participants suggested non-smartphone options for people who are not proficient with them.

Tangible interfaces, such as tactile interfaces (e.g., tablets) and clearly marked buttons, were cited as common input to enable interaction with a diverse range of customers. Participants shared the importance of on-body inputs to enable easy interaction with delivery robots by non-high-tech customers without smartphones, which Pittsburghgirl noted would be useful for sending resources to members of her community; this idea was also echoed by sleepsong, who touted the benefits of "redundancy" (W2). Furthermore, tactile or touch-sensitive input could activate an alarm to deter bystanders from attempting to take items from the robot while en route (Gabriel, W2). Finally, some participants also showed interest in the use of biometrics to unlock the robot's grocery compartment.

Participants also suggested **verbal communication** [171, 172]. Many participants were guide dog users and wanted delivery robots to be similarly capable of following them to their apartments for drop-offs. Robots that support diverse human communication via voice interaction and natural language capabilities should account for diverse accents, including disability-specific speech variations, the latter of which Pittsburghgirl stressed. Also, Pittsburghgirl, who uses sign language, expressed "I would love to see [...] an ASL robot" (W1), communicating the desire to communicate with delivery robots in **gesture-based languages**. Participants also expressed desires for **interoperability with Augmentative and Alternative Communication (AAC)** [26], which can be "no-tech", such as observing facial expressions; or 'high-tech', such as speech-generating devices and text-based interfaces. Gabriel noted, "There's just like a puffer tube. [...] Some of the commands could be like unlock, lift, slide if it's coming out to the side."

2) Communication From Delivery Robots. Just as accessible communication is important for bystanders (e.g. [172]), it is also critical for customers. Several participants suggested various modalities for communication. They shared that **visual cues**, such as signal lights and flags, can be helpful for low vision customers to ensure rendezvousing with a delivery robot. Similarly, diverse output modalities, such as *gesture-based* and **text-based** communication, are also critical to support diverse local communities. Participants also suggested **auditory cues**, which include speech and non-speech. Gabriel and Mocha envisioned delivery robots indicating their location to BLV customers by producing auditory cues similar to those emitted by electric vehicles (EVs) or an Air Tag. R.J. added that specific verbal instructions and directions from the robot could further assist with locating it (e.g. [369]).

Some participants discussed their preferences for **speech characteristics** of the delivery robot. While Mickey had preferences for a human-like ("realistic") sounding voice, Astrid preferred a computerized voice. She shared that 'I think after [delivery robots] have been around for a while, people [will] hear the computerized voice [and think] “oh, that’s the [delivery] robot.” Astrid, who also has a hearing disability, and Mickey suggested that sounds must be **automatically-modulated** based on ambient noise to ensure they are perceivable by people with hearing disabilities (W2).

4.4.3 Customizable and Personalizable Interactions

Participants articulated their desire for personalized and customizable interactions with delivery robots that were considerate of disability-specific as well as social and cultural factors.

Disability-Awareness: Proxemics and Notions of Space

Proximity in bystander interactions with PwDs [38, 172] has been explored with respect to importance of right-of-way for people using mobility devices/aids. These notions were echoed by several participants, who also considered bystander interactions for PwDs. Kassandra noted safety issues: “If [the robot] didn’t detect someone in [...] a manual wheelchair, they could potentially push that person into the middle of the street” (W1). Participants also shared the importance of **close proximity interactions** for people with sensory disabilities, including people with hearing disabilities and pBLVs – an idea that R.J. evoked while exploring the distances from which he could hear specific sounds. Close interactions were seen as critical for **facilitating handovers** with PwMDs for whom reaching can be difficult. Kassandra noted: “a person in a wheelchair has to get closer to the robot to be able to scan their phone and grab things out.” Heavy items were also highlighted, with sleepsong noting: “I can’t carry bags very far [...] If I had a robot delivering stuff, I would not be able to take care of the delivery on my own. I’d need someone to help me [...] put stuff away”(W1). Thus, many people with limited mobility shared ideas about the robot helping with post-delivery processes, such as putting items away (see 4.4.6).

Several participants discussed **height considerations** for SDRs, in particular. LGP noted that there is variability in the heights of wheelchairs, which delivery robots do not take into consideration. Similarly, sleepsong suggested that customers be able to adjust (i.e. **cus-**

tomize) robot height through voice commands or buttons to enable customers in wheelchairs to retrieve their items. iamcool added the idea of **personalization** of automated height adjustments for specific users depending on wheelchair height.

Socially and Culturally Appropriate Behaviors

Participants suggested that delivery robots should be capable of socially appropriate behaviors. This is most pronounced in *social navigation*; for example, Mickey suggested delivery robots adhere to foot traffic conventions, such as waiting for people to pass; he encouraged the use of "politeness" as it "encourages people a little more" [182]. Furthermore, he suggested that robots communicate their directionality, which is important for pBLV passersby: 'I'll be on your right or I'm gonna be on your left' (W2). Similarly, others suggested that delivery robots be aware of cultural norms. For example, iamcool evoked the idea of delivery robots "taking off" or cleaning off shoes before entering households, which is common across many cultures. Although iamcool was uncertain about "how effectively a robot can use" a doormat to wipe its wheels, he suggested the robot respond to verbal commands, such as to wait while he cleans its wheels prior to its entry. This latter idea is important for post-delivery assistance (see 4.4.6).

4.4.4 Delivery Safety and Malfunction Support

The participants shared ideas on the *safety of their deliveries*, which depended on the type of delivery. Some participants discussed safety measures for unattended deliveries, such as SDR compartments having a **detachable lockbox**, which could be left at a specified location near the user's residence. Moreover, *cost* and *sustainability* prompted them to consider how robots could **interface with existing lock-boxes** at the front of residences. For attended delivery, participants preferred that the robot compartment remain locked. They speculated on high- and low-tech options to unlock the robot compartment, including near-field communication (NFC) between smartphones and the robot or passcode via keypad or touchpad on the robot's body. Regardless of delivery paradigms, participants urged that compartments must be insulated to maintain the quality of medications and food items. They also noted that robots should either **automatically sanitize compartments** or have covers to prevent contamination by allergens or germs. This was surfaced repeatedly by Pittsburghgirl, who works as a geriatric nurse to immunocompromised adults, some of whom have allergies.

Participants discussed **alarm mechanisms** to deter bystanders from vandalizing "or meddling" (Mickey) with ADRs en route. iamcool, who shared that he would allow the robot to enter his home while he was away, discussed safety precautions for preventing burglars from following the robot into his home: "A robot can have a camera and things like that, you know. If the law allows it, [the robot] can electric shock that person [...] [or use] bear spray." Participants also discussed robot malfunctions en route, near, or in their residences. iamcool suggested "robot roadside assistance" provided by the robot's company. LGP echoed similar ideas. Kassandra added the importance of hasty deployment of technicians if the robot fails en route to ensure package delivery or refunds. But she remarked that **transparency with the customer** (e.g. [376]) about the origin of the problem is critical because it may suggest routine flaws.

4.4.5 Accessible Robot Features and Form Factors

Our participants offered significant insight into the capabilities of different mechanical systems due to their experiential knowledge with their own or community members' mobility devices. For example, sleepsong, LGP, and Kassandra - all PwMDs who use power wheelchairs – were acutely aware that SDRs had severe limitations due to the poor sidewalks and steeply sloped neighborhoods in our city. Additionally, sleepsong shared that many SDRs would get stuck in cobblestone sidewalks in her neighborhood due to their small wheels (W1). As such, several participants suggested *environmentally appropriate* features for delivery robots, including all-weather, high "traction" wheels, and winterized bodies for operation in inclement weather. Furthermore, our participants were keenly aware that: "depending on the house, depending on the type of disabilities you have, you can have several different shapes or models of [delivery] robots" (iamcool, W2). They offered several features that they considered *architecturally appropriate* to perform delivery tasks in various types of buildings. The participants brainstormed legs, different chassis configurations

(Abraham and Gabriel in W2), and tri-wheels [372] (Astrid, W1) for climbing stairs or ambulating on uneven terrain (Fig.4.3).

Features recommended by the participants, particularly types of motions, suggested other form factors beyond those of SDRs. For example, **delivery drones** could be beneficial when faced with a *lack of appropriate transportation infrastructure* that a SDR could use – a point that Mickey added due to the lack of sidewalks in his suburb; and by Abraham, who speculated about the potentials of delivery drones or legged robots in *remote areas*. Mocha, who lives in a high-rise apartment suggested that "a drone [...] could hover at the window and I could take the food out," or land on a customer's balcony (W2). Moreover, she speculated that delivery drones could be more efficient, particularly for the fast delivery of "food items."

Despite the utility of this form factor, participants also considered the **limitations of delivery drones**. The first they cited was 1) *Payload*. Mocha shared that "a 40 pound bag [of dog food] [...] might be too much for a drone. But [...] it could bring smaller packages" (W1); 2) *Safety considerations*. In a diary reflection, Astrid questioned whether grocery and food items delivered by drone would be safe from **theft**, assuming that unlike an SDR, they would have no locked compartment; 3) *Privacy*. Finally, Effdi cited concerns about privacy when using delivery drones: "The big thing for me is privacy[...] It's the public seeing everything when you [are] just trying to live your life [...] just bring it to my door."

Furthermore, participants expressed their desire for robots to **press** the intercom and elevator buttons and **knock** on their doors upon arrival, the latter being a social norm. Thus, they discussed delivery robots having arm and hand-shaped appendages, a design feature that can also facilitate accessible handovers. For example, Pittsburghgirl suggested that the robot have "retractable" arms for providing physical assistance by placing items on the lap of PwMDs who are wheelchair users. In addition, sleepsong suggested a "**hydraulic lift** that can lift your order up to you," a design feature that she likened to one that her power wheelchair has; the latter idea was also represented in the co-designed mock-up in W2 sessions. Finally, participants shared preferences for the **sizes of delivery robots**. Participants were concerned about the **carrying capacity and weight limits** of delivery robots. For example, R.J. and Effdi (W1) were not enthusiastic about their space and weight limitations, which they deemed too restrictive to meet their needs. However, the **size of the**

robot should depend on the environment: "I like the smaller size of the robot because it's less of a safety risk" (Pittsburghgirl). Furthermore, participants suggested *compact robots* in settings with limited sidewalks or narrow roadways.

4.4.6 Delivery Robots and Their Roles

Several participants were excited about the opportunity for delivery robots to provide them with post-delivery assistance. The humanoid robot form factor evoked fear and discomfort in a range of participants (mostly those who could visually perceive it), leading most participants to ideate around SDRs, which they viewed as more friendly. However, for participants, for whom the humanoid form factor mirrored that of a human caregiver, they noted its utility. For example, Kassandra, who orders when she has a caretaker to bring things in and pack them away, preferred a humanoid delivery robot; she speculated that it "would probably be better since I'm not able to physically reach [...] and grab things." Furthermore, iamcool brainstormed a delivery robot with a **barcode reader** to scan items as he removes them from the compartment to help him *identify and confirm* delivered items. He described the capability to *query the robot for additional information* about each item (e.g. cooking instructions) (W2). Moreover, Mickey brainstormed about the delivery robot being able to **return items** to the store – an idea that was echoed by several other participants. However, in Mickey's idea, he envisioned the delivery robot operating like a **shopping assistant** that could give him feedback on his visual appearance when trying on new clothes (W1); the robot could also **automatically refund** money for items that he did not plan to keep. Finally, iamcool suggested the benefits of a delivery robot helping him with assembly of new furniture, either with the construction or with helping to *identify items and where they fit in the assembly*: "if the robot can help me [with assembly] or orally, even that would help. But if it can do it by itself, that's nice too. That's another feature" (W2).

Some participants also contemplated the *ethical ramifications of delivery robots that provide auxiliary support*. For example, Pittsburghgirl offered an idea for delivery robots en route informing people with visual disabilities when to cross the street (W1), presumably when audio crossing signals are not working/available. However, based on her lived experience, Gabriel cautioned against delivery robots telling pBLVs to cross the street if *the crosswalk signals were not working and the robot misinterpreted this* – citing fears about intelligent systems providing incorrect information (i.e., AI "hallucinations"), that could be life-threatening.

4.4.7 Social and Ethical Tensions

Some participants were **optimistic** about delivery robots, which they perceived as being more morally trustworthy [265] than delivery people; some of this is rooted in their negative experiences with delivery people (see 4.4.1). For example, Effdi shared "The robot is not prejudice[d]. The robot is not ableist, as the robot does not judge. The robot [gives] you your stuff and [goes] on its way. That's all I want" (W1). However, some participants were **skeptical** about the potential of delivery robots to disrupt delivery employment for vulnerable populations. For example, sleepsong had previous experience advocating about the detrimental impacts of premature deployments of SDRs on sidewalk access, particularly for local PwDs. For her, improving the accessibility of delivery robots was a means of *harm reduction*, particularly for members of the disability community: "I just don't like them at all, but I recognize they're going to happen [...] so I might as well make sure they're as accessible as possible"(W1). sleepsong's skepticism enabled her to write a counter-narrative [42, 379] (Fig. 4.3) in which she articulated critical steps that delivery robots need; that is, **handling complex interactions with humans**. sleepsong ended her story with her desire to have delivery people instead of robots.

The tensions in values and experiences between participants yielded fruitful discourse. For example, sleepsong and iamcool, who have different perspectives and lived experiences with disability, were in a group together; this allowed them to confront these tensions. For example, iamcool shared, "I just want to be safe. I want my things delivered [...] I don't trust people coming in [when] I can't see what they're doing [...] I have no choice." He added that he has "no issue whether it is a delivery person versus a robot' as long as he "can always find [his deliveries at a] consistent location" (W2). For some PwDs, the use of delivery robots can provide opportunities for consistent and reliable access to life-sustaining resources, especially since there is so much variability in delivery people. Participants showed interest in **mixed human-robot delivery paradigms**. These discussions prompted further considerations: 'I think depending on *why* [companies] are using robots [for example, whether it is] just really to save money for delivery [by] not having the delivery person [...] maybe the *robot can carry things* from the truck to the residence [...] there could be some *people with bad knees [who] can still drive* [...] but the robot can actually carry things' (iamcool, W2). Here, these tensions fostered discourse around paradigms that can support disabled workers; however, more work needs to be done to understand the unique challenges and desires of disabled workers. Still, there are roles where human assistance will remain paramount. For example, Gabriel and Pittsburghgirl shared their **preferences for human customer service** as compared to chatbots. Both of them repeatedly stated their preferences for humans, who are capable of *empathy*, saying for example: "[a] person could tell you what food tastes good because they actually eat it. The robot doesn't know" (Pittsburghgirl, W1).

Delivery Robots & Low-Income Communities

Our participants hailed from different neighborhoods but a common factor is that many lived in **low-income communities**. For example, sleepsong commented on her discomfort with neighbors observing her receiving items from a delivery robot 'to have some [fancy] robot bringing me [a package] instead of having a person [...] no, I don't want that' (W1). For residents of low-income neighborhoods, high-tech, such as robots, can conjure negative associations (e.g., impending gentrification [218] and divestment from public resources towards private ones [38]). To counter this, Mushy and In-Remission-Man stressed the importance of **gradual introductions** of delivery robots, citing diverse and fearful social perceptions of unfamiliar high-tech systems. For example, Mushy quipped that while Digit, the humanoid robot would be antagonized, Starship's SDR would be perceived as less threatening. Similarly, In-Remission-Man observed it may just prompt "curiosity." He suggested that delivery robots could be introduced gradually to communities, offering potential venues like **senior centers and libraries** where people can "watch [delivery robots] in action so that they can be familiar with it before they see it." He added that it is particularly critical for vulnerable communities: "You got to introduce [delivery robots] to the people that will be affected the most."

4.4.8 Methodological Insights

We asked participants to provide reflections on our short-term, longitudinal co-design process. In general, the participants expressed their approval of the design process. Although some participants desired deeper engagement with a robot prototype. For example, Abraham noted: *"Interacting with a functional robot in addition to a mock-up would have been interesting. I suppose such a robot does not yet exist"*. Furthermore, although some participants were unsure whether their ideas were evolving, retroactive reflection enabled them to understand the value of longitudinal engagement in their design ideation. For example, iamcool shared:

> "I often felt like I kept repeating myself and wondered if I was really contributing to your project. I then noticed that I was giving a little different ideas each time. My thinking about robots have evolved each time when I attended your in person sessions and doing my diary. Not saying good or bad, but probably I have contributed more when I was there one on one rather than having another participants with me, but this had to do more with my personality. I enjoyed both settings."

Furthermore, participants acknowledged the value of mixed-disability workshops. For example, sleepsong who was in a session with iamcool, shared:

> "It's been very interesting in participating in these workshops. The other person with whom I interacted had a VERY different type of disability, and that really brought in some new perspectives that I'd never really thought about before."

Finally, Pittsburghgirl, who is profoundly deaf, expressed desires for more inclusive participation in comparison to her group members, sharing:

> "[You] went above and beyond to guide the blind participants to the study location. [...] One [piece of feedback] is to offer closed captions, or an ASL interpreter, if funding is available, if you ever have another deaf participant."

This highlights our failures to provide equitable and full participation for our participant with a hearing disability, who had to rely on "read[ing] people's faces." This created missteps in groups. For example, Pittsburghgirl unknowingly interrupted Gabriel, who is blind – an incident that could have been mitigated by the use of appropriate accommodations within groups with diverse access needs. Future work must ensure that in mixed disability workshops the access needs of each participant are balanced and do not fall short of other members.

4.5 Discussion

It is crucial to consider the varied experiences PwDs have with OD/LMD. Previous work on OD/LMD focused on use among non-disabled populations (e.g. [333]). We affirmed that many PwDs use OD/LMD for reasons related to accessibility [295]. The majority of our participants face additional socioeconomic hardship [61] and live in low-income communities with few resources [68]. OD/LMD connects them to valuable and life-sustaining resources [114]. Our participatory design workshops helped surface these motivations and challenges, which were critical in helping our disabled co-designers to (re)design delivery robots to better support their needs and the needs of their communities.

We summarize practical insights for delivery robot design and incorporating pluriversal approaches for the broader HRI community, especially when working with PwDs.

4.5.1 Recommendations for Future Delivery robots

We summarize recommendations for designing and deploying accessible delivery robots.

Accessible communication modalities. We uncovered varied and inclusive communication modalities our disabled co-designers suggested beyond voice interaction [172]. Participants suggested tangible inputs, such as buttons, to ensure access amongst their low-tech community members; they also suggested *gesture-based inputs* [20, 374], and interoperability with *AACs* (e.g [26, 404]), both of which are underrepresented communication modalities in robotics.

Diverse form factors & features. The specific form factor and features for delivery robots is context-dependent; the contexts include the specific access needs of the customer and tasks customers' want the robot to assist them with (either prior to drop-off, during drop-off, or post-delivery), and infrastructure constraints. Unlike in previous work [171, 172, 253], we enabled participants to (re)design delivery robots to have a variety of form factors and features to ensure robots that support their *accessibility needs*. Participants considered the pros and cons of certain form factors with respect to their *local infrastructure and residences*; they described different tasks they wanted delivery robots to perform in a range of environments and envisioned delivery robots having features that would allow them to *climb stairs and press elevator buttons*. While many companies operate homogeneous ADR fleets, this work demonstrates that PwDs recognize the utility of fleets composed of robots with different form factors. Companies and researchers could rely on user feedback about disability-access needs from PwDs and crowdsourcing infrastructure and residential accessibility [345] to assist with selective deployment of delivery robots with specific form factors. Still, participants were conflicted about larger delivery robots for bulk shopping to avoid additional fees incurred by frequent deliveries versus bystander safety.

4.5.2 Pluriversality in Robot Design.

This is done by embracing the three key principles. Note that these principles make up the principles and sub-principles of the Lived Experience Framework (see Fig. 1.1).

Tensions in the design process. Pluriversal approaches enable co-designers, including researchers, to respect differences in lived experience [298], including disability and other social factors; as such, our disabled participants were able to have fruitful discourses about how these different perspectives can yield equitable interactions with delivery robots (see 4.4.7). They discussed social and ethical considerations for delivery robots in local communities to ensure equitable introductions that do not further ostracize PwDs, many of whom live in low-income communities (e.g. [175]).

Centering affected PwDs' lived experiences. PwDs can provide valuable suggestions for accessibility features that may support other PwDs with different disabilities. Our participants in mixed disability workshops were able to provide additional ideas about features that could support other group members (see 4.4.3). However, their suggestions could be limited. In previous work, PwMD and non-disabled co-designers envisioned delivery robots that could provide *auxiliary assistance* to pBLVs crossing the street [172]. Although a PwMD echoed a similar idea in our work (see 4.4.6), a pBLV noted a robot making erroneous suggestions could be life-threatening.

Researcher Reflexivity. We encouraged participants to envision solutions to their OD/LMD challenges beyond delivery robots, which is central to pluriversal design [406]. Here, *researcher reflexivity* is vital [406] as it encourages researchers to be aware of their own biases, which may be technology-oriented, and to defer to the needs of community members.

4.6 Summary

In this work, we explored how PwDs would (re)design delivery robots. We used a pluriversal approach to conduct a series of participatory design workshops with diverse local PwDs. This resulted in diverse design recommendations, including varied communication modalities, delivery robot form factors, and different environmentally- and task-specific features to meet the needs of PwDs. This work also demonstrates that design engagements that end with disparate results are not flawed – they represent the diversity of the human experience.

Service Robot for Last-Mile Delivery Takeaways

1. Delivery robots should support redundancy in communication input and output (I/O) modalities to support broad populations.
2. Enable support of inclusive modalities, such as gesture-based languages, interoperability with Augmentative and Alternative Communication (AACs), and the use of tangible on-body interfaces, such as keypads.
3. Enable customizable and personalizable interactions. For example, the height of the delivery robot compartment should be adjustable by end-users or should automatically adjust to ensure accessible reaching.

4. Delivery robots should demonstrate socially and culturally appropriate behaviors; for example, saying “excuse me” or enabling tire cleaning before entering households.
5. Delivery robot form factor and morphology are context-dependent, assigned by end-user’s disability-related access needs, tasks they need help with, and the infrastructure.
6. Delivery robot companies should provide comprehensive malfunction support; additionally, they should provide public opportunities to allow local residents to interact with delivery robots before widespread deployments.

Methodological Takeaways

In this work, I demonstrated that:

1. Pluriversal co-design processes are equitable as they enable PwDs who are non-practitioners to communicate ideas in ways that are beneficial.
2. These approaches encourage embracing tensions due to differences in lived experiences, which help surface novel inclusive and equitable design ideations, many of which consider socio-economic and diverse disability perspectives.
3. Finally, that researcher reflexivity is critical to cede design power and embrace technological refusal in favor of the futures that PwDs envision for themselves and their communities.

These takeaways illustrate the application and results of applying the **Lived Experience Framework**. In Chapter 7, I will demonstrate how this approach can be utilized in a separate domain, mental well-being.

Part IV

Designing Service Robots with Adults with Mental Health Disabilities

5 Towards Social Robots for Marginalized Adults with Mental Health Disabilities

Part of this work is featured in *Boadi-Agyemang, A.*, & Park, M.* (2024). Designing interactive agents to support emotion regulation in the workplace through guided art-making. In Companion of the 2024 ACM/IEEE International Conference on Human-Robot Interaction.* [47]

5.1 Motivation

Mental health conditions are embodied [76, 315]. There are no empirical measures to discern mental illness [130]. Therefore, the first-person accounts of people with mental health disabilities are vital. Nevertheless, in most mental health related research, the lived experiences of people with mental disabilities are left out in favor of clinical perspectives, thus embracing medical models and ignoring the social realities of people with lived experience of mental illness [130]. My identities and experiences with mental health disabilities, including living with debilitating anxiety, panic, and depression for which adequate care has been limited by racist and sexist assumptions about what disability looks like (e.g., [72]) – and experiences with marginalization are critical in motivating my epistemological and methodological positions; they inform my desire to design socially interactive agents and socially intelligent robots with and for people with mental health disorders. The focuses of this work, while grounded in psychology literature, are also inspired by my experiences with psychotherapy, including creative arts psychotherapy, and the opportunities for socially intelligent robots to support mental well-being.

5.2 Introduction

Mental health is a "state of mental well-being" that allows people to "cope with the stresses of life, realize their abilities, learn and work well, and contribute to their community" [313]. Globally, mental health conditions are among the most common disabilities. According to the World Health Organization (WHO), in 2019, 1 in 8 people (970 million) on the planet had a mental disability, with anxiety and depression being the most common [419]. In the U.S., a 2021 survey from the National Institute of Health (NIH) estimated that 1 in 5 adults (57.8 million) in the had a mental health condition [303].

Despite these staggering figures, many people in the U.S. do not have access to mental health resources. In fact, a recent survey found that only one-third of U.S. adults reported being able to access mental health services that they need [211]. There are several barriers to accessing mental health resources [52]: geographical location and availability of licensed therapists; high co-pays and insufficient insurance coverage; language and cultural mismatch between patient and therapist; and lack of mobility or transportation. Furthermore, there are discrepancies among who is able to receive care for these conditions.

Digital mental health tools have been used to overcome barriers to mental health access Still, many technologists ignore the factors that exacerbate mental health. There are several determinants of mental health conditions, including social factors (e.g., race and ethnicity, socioeconomic status) and environmental factors (e.g., trauma, adversity, and stress) that contribute to the development of mental health disorders [113]. Similarly to digital mental health tools, robots used to support mental health tools are rarely developed with vulnerable populations in mind. Thus, failures to consider social determinants of mental health when designing mental health technologies presents challenges to the efficacy of technologies to support vulnerable populations [219].

In this chapter, I conduct a literature review summarizing the evidence-based interventions used by health practitioners and mediated by digital tools to support people living with anxiety and depression. Furthermore, I highlight gaps in the types of evidence-based interventions that socially assistive robots facilitate to aid the mental health of human users; moreover, I also highlight gaps in the target populations represented in HRI mental health research. Finally, I provide motivation for designing robots that improve social rapport with their human users during joint activities and how these insights can be used to design robots that can support vulnerable populations.

5.3 Literature Review

5.3.1 Theme 1: Strategies for Coping with Anxiety and Depression

Emotion regulation is the process by which people can impact the emotions they choose to express and how they experience these emotions [160]. Gross's pivotal framework on emotion regulation strategies (ERS) [160, 161] includes strategies like seeking situations or people that make you feel good; engaging in distraction; or re-framing one's perception of a situation, to name a few. In [160, 161], ERS can be broadly categorized into antecedent and response-focused ERS. Antecedent-focused ERS provide support before an emotional response has unfolded and includes seeking situations or people that make you feel good (i.e. Situation modification); engaging in distraction (i.e. Attentional deployment); or re-framing one's perception of a situation (i.e. Cognitive change/appraisal). Response-focused ERS involves modulating one's physiological, behavioral, or experiential response once these responses have arisen (i.e. Response modulation).

Research hypothesizes that anxiety and depression are the result of emotion dysregulation of negative negative affect coupled with reduced positive affect [186]. Moreover, researchers also theorize that clinical conditions, such as anxiety and depression, are the results of dysregulation in multiple stages of the emotion regulation process [367]. For example, researchers speculate that anxiety disorders arise from a person over-representing a perceived threat, resulting in failing to disengage their attention from that perceived threat [367]. Similarly, people with major depression may have difficulties with taking action to resolve negative emotions, such as distracting oneself with positive memories to improve their mood [367].

Mind-body therapies (MBTs) promote bodily awareness and response to negative stimuli that result in emotion dysregulation [326]. MBTs include breathing and relaxation, yoga, art therapy, music therapy, dance, mindfulness, guided imagery, qigong, and hypnotherapy, to name a few [119, 136]. They have been effective in treating depression and anxiety among older adults [119] and have been found to be effective in helping to manage somatic symptoms [202, 216, 361]. Researchers hypothesize that "interoceptive awareness", or "the processing of inner sensations so that they become available to conscious awareness" is integral to MBTs [326]. For example, during mindfulness-based activities, people are encouraged to bring attention to their bodily sensations, reflect on the sensation, which may enable them to re-frame or reappraise their perception of the situation that caused their emotional response.

Art therapy is a type of mind-body intervention and psychotherapy approach that uses creative expression to promote mental well-being [264]. Art therapy is facilitated by a licensed art therapist. In contrast, therapeutic art-making, which can include art therapy, does not always require specialized facilitation and can be practiced individually [323] (e.g., painting as a hobby can be therapeutic). Art-making as both a psychotherapy and independent practice has been used to minimize symptoms of mood disorders, such as depression [168] and anxiety [6]; treat cognitive impairments, such as dementia [110, 412] and psychotic disorders [81]; support trauma victims [359]; reduce occupational stress [194, 410]; and help patients cope with physical symptoms, including pain [294, 377].

5.3.2 Theme 2: The Role of Technology in Coping with Anxiety and Depression

There are different types of digital health options, including health information technology (IT) and mobile health ("mHealth"). Health IT is health-related communication between health provider and patients/clients, including secured messages, emails, and telehealth videoconferencing [25].

An example of Health IT is telerehabilitation, which is the use of communication technologies to provide rehabilitation services [398]. Telerehabilitation relies on physical movements communicated by a physical therapist, at a distance, that need to be performed by a patient. Prior work has shown that telerehabilitation is on par with in-person physical therapy for some conditions [364]. Immersive technologies, such as VR, have also been used in telerehabilitation. Research findings indicate that VR-based telerehabilitation can support regaining balance-related locomotor skills [255]. Furthermore, participants found the VR-based telerehabilitation system to be usable and motivating, factors which positively impact adherence to an intervention [12].

mHealth is the use of "mobile and wireless devices to improve health outcomes" [25]. Associated technologies are smartphone wellness applications, wearable devices, such as smartwatches and digital therapeutics [25]. Previous work has also demonstrated that digital health tools can provide therapeutic support [332, 414]. Examples include mobile health apps, such as Calm and Headspace, which offer guided mindfulness interventions. Research has shown that for people dealing with mental disorders who recognized their need for treatment, more than 60% of them wanted to handle their mental health problems on their own [17], making the use of personal well-being an attractive option.

Almost half of U.S. adults engage with interactive agents, specifically digital assistants (e.g. Apple Siri), in their daily lives [311], making them a viable accessible option for mental well-being support. Interactive agents can be designed to have social presence, which are behaviors and aspects of an interaction that impact the relationships formed [260]. Socially interactive agents (SIA) [135] are "systems that show human style social intelligence" [103]. These agents have been used in mental health and mental well-being contexts [152]. Moreover, SIAs can be categorized by their embodiment into two categories: conversational user interfaces (CUIs), such as digital, voice-activated assistants or virtual avatars, and social robots.

Social robots (SRs) are those capable of social interaction with humans and have been used for diverse applications across education and health settings [56]. Under the paradigm of social robots, or socially interactive robots [135] and assistive robotics, Socially Assistive Robots (SARs) [131] provide different types of assistance through social interaction [268]. SARs have also been used in physical rehabilitation. For example, a SAR can use encouraging feedback styles to motivate older adults to perform rehabilitative exercises [268]. They have also been used in the context of mental and cognitive healthcare [327], including with elderly people who have dementia and depression and young children with autism spectrum disorder (ASD) — the latter of which has problematic socio-ethical underpinnings and outcomes [421].

In contrast to digital SIAs, social robots' physical presence is associated with improved social engagement with their users, which has been found to reduce depression and enhance positive affect [57]. Furthermore, a review article found that social robots are perceived as more persuasive at health-related behavior change tasks than a virtual agent with the same appearance [249] – making SARs more advantageous for clinically relevant mental health interventions than digital SIAs.

Although social presence via physical embodiment may be beneficial, it may not always be cost prohibitive. Using existing technologies is more cost-effective as this reduces the need for users to acquire new forms of technology [429]. Re-embodiment (an agent moving its social presence from one body to another, along with its identity, acquired knowledge, and skills) [121] is one approach to circumvent this issue. For example, the movement of social presence between a conversational agent and social robot may provide additional affordances based on the existing technologies they currently possess. Furthermore, this fluid movement between embodiments may enable social agents with these capabilities to acquire specialization as they move in between embodiments, adapting their behaviors, and updating knowledge to better support users by performing specific tasks [260].

5.3.3 Theme 3: Supporting Mental Health in HRI

In HRI, robots have been used to support a range of clinically-relevant mental health tasks and provide support during daily activities [152, 327]. To support these tasks, SARs take on three specific roles: coach, or instructor, companion, and play partner (although the latter is most relevant to interactions with children with ASD) [327].

Companion robots can behave similarly to a therapy animal. For example, Paro, a baby-seal like robot provided companionship to elderly adults during their daily activities (e.g., craft making and bingo sessions) and improved symptoms of depression and mood, and reduced loneliness in elderly adults [340]. Moreover, a coach/instructor SAR can instruct or supervise a person during an intervention. For example, researchers developed Ommie, a robot that guides users through deep breathing interventions; while holding the robot, its torso expands and contracts and vibrates to provide haptic cues the user [270].

SARs have been used as play partners with children, a population out of the scope of this work, and there is relevance of a play partner's social behaviors with respect to social engagement. HRI researchers designed Keepon, a social robot, to encourage normative social communication in children with ASD [220]. Interpersonal coordination is behavioral alignment (I introduce this concept in Chapter 6). In children with ASD, differences in social development mean reduced spontaneous synchronization of body movements, speech, and emotion. Furthermore, interpersonal coordination is also crucial for successful joint actions, such as collaboratively moving heavy objects, to ensure successful human-robot teams [198]; it has also been explored to improve closeness and rapport [143, 390].

SARs have been designed to support a range of MBTs and recent work has explored the use of virtual and embodied agents to support mindfulness. Shi et al. [368] conducted a multi-phase study aimed at understanding the impacts of user-personalization and embodiment on perceived quality of a mindfulness-based agent. They explored the use of no agent, a conversational agent, and a socially-assistive robot. They found that user-personalized characteristics of text-to-speech (TTS) voices are perceived almost similarly to human voices. While prior work suggests the benefits of embodied agents, they hypothesized that mechanical noises emanating from the embodied robot distracted their participants from the mindfulness exercise. For this reason, it is worth exploring whether a virtual agent can support therapeutic art-making without the distractions of a physical system.

Interpersonal coordination has also been used to encourage emotion regulation in HRI. For example, researchers designed a robot that synchronizes its visual behaviors (e.g. lights, motions) with the physiological responses of a user, specifically their heart beat and breathing rate [436]. They conducted a controlled experimental study; some participants reported that the robot's synchronized behavior resulted in improved awareness of their own emotional state, which promoted emotion regulation. Furthermore, they found that the robot's synchronized visual behavior improved participants' perceptions the robot's safety, animacy (i.e. life-likeness), and likeability. This research suggests that coordinated robot behaviors has implications for the social rapport between users and SARS as well as regulatory benefits.

Research has also focused on the role of intelligent systems in supporting a person's cognitive [184] and mental [92] well-being by facilitating MBT-inspired interventions, such as therapeutic art-making and art therapy. Several studies have focused on the role of virtual and embodied agents in collaboratively creating artwork with humans on their psychological and mental health [58, 92, 205]. Although prior work highlights the effectiveness of therapeutic art-making, there is a gap in HRI research that demonstrates the use of these SARs to support therapeutic art-making.

5.3.4 Theme 4: HRI and Underrepresented Groups with Mental Health Disabilities

Although HRI research has demonstrated the value of SARs for supporting the mental well-being of people with anxiety and depression, the demographic groups targeted are narrow. Research on SARs focuses primarily on older adults and children [152] and HRI, more broadly, regularly fails to document the sociodemographic categories associated with the populations they engage with, including race and gender [360]. Similarly, when designing SARs to suport populations, HRI practitioners prioritize the design participation of professionals, such as therapists, instead of the intended users. Nevertheless, evidence-based research on digital mental health tools shows the impact of inclusive technologies on the well-being anxiety and depression [272, 273, 274, 310]. Research has shown that intended users of SARs who are involved in the design process feel more empowered [322].

5.4 Discussion

There are several gaps and promising directions that I seek to explore in the following chapters. First, while SARs engage users in clinically relevant interventions, there is value on incorporating underexplored mind-body activities, such as art therapy. In subsequent chapters, we leverage art therapy inspired activities to understand the role socially interactive agents can play in facilitating emotional regulation. We also explore socio-cognitive factors that are essential for socially intelligent robots that engage with humans in joint art-making — a form of dyadic art psychotherapy [63].

Second, although HRI practitioners explore interpersonal coordination for encouraging normative social communication and improving human-robot collaboration, there are several regulatory and prosocial benefits of this phenomena. One example is coregulation, "a bidirectional linkage of oscillating emotional channels (subjective experience, expressive behavior, and autonomic physiology) between partners; this phenomena contributes to emotional and physiological stability for both partners in a close relationship" [67]. Co-regulation occurs in several interpersonal dynamics, such as between romantic partners (e.g. [95, 133]) and between patient-clinician dyads (e.g. [217]). Linguistic synchrony has regulatory effects, facilitated through the "behavioral and physiological modalities of interpersonal synchrony; [217]. For example, when people engage in conversations they "coordinate their postural sway [to] match another [person]'s eye gaze, even when they cannot see each other" [373]. Furthermore, "conversation[s] synchronize breathing rates" [277], which in turn regulates cardiovascular responses [241]. These theoretical underpinnings could be used to inform how supportive agents could adapt their behaviors to encourage emotion regulation, in people experiencing distress. HRI practitioners could explore other manifestations of interpersonal synchrony that are integral to certain mind-body activities, such joint breathing.

As noted, SARs research rarely focuses on marginalized populations and it is crucial to consider how social determinants of health impact the efficacy of SARs for supporting positive mental health outcomes. Racism is a a social stressor [87] — it is social determinant [329] that is linked to presence of mental health, or psychopathology [415]. Black Americans have a long history of social and economic oppression and political disenfranchisement, which contributes to negative health outcomes [85]. HRI practitioners must integrate the lived experiences of marginalized people when designing and evaluating SARs to ensure equitable mental health outcomes.

5.5 Next Steps

In the next two chapters, I apply theory of the Theory of Mind (TOM) and participatory approaches design to design socially intelligent robots [56] and as applications of lived experience. The goal was to uncover interpersonal dimensions that impact the social relationship in joint human-robot activities that lead to human acceptance of robots for mental well-being tasks.

First, I document a comparative study to investigate how interpersonal synchrony in joint art-making, an art therapy inspired intervention, influence people's perceptions of a socially interactive robot prosocial tendencies (i.e., empathy; see Chapter 6).

Second, I engage the lived experiences of members of marginalized social groups with anxiety and depression to co-design SARs. Here, I integrate findings regarding different clinically-relevant interventions, including mind-body therapies, robot social behaviors, and robot embodiments and social presence. I conduct a speculative co-design study of social robot-mediated mental well-being for Black women with anxiety and/or depression (see Chapter 7).

6 Designing Robots for Mental Well-being

Part of this work is featured in *Boadi-Agyemang, A., Schaldenbrand, P., Misra, V., Carter, E. J., Oh, J.,& Steinfeld, A. (2025). If I Move, Do You Move? Investigating the Role of Interpersonal Synchrony in Human-Robot Joint Painting. In 2025 34th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN) (pp. 728-735).* [48]

Interpersonal synchrony (IS), the behavioral and physiological coordination across time and space, plays a crucial role in social interactions by fostering empathy, closeness, and prosocial behaviors. However, there is a need for more examination of HRI research focused on interactions where the temporal alignment of body movements and the spatial coordination of the content produced by those movements is vital to the quality of the interaction, such as in joint visual art-making. In this work, we investigated the impact of IS on human raters' perceptions of a human-robot (HR) dyad engaged in a joint painting activity. We conducted two online studies (n = 70, total) in which participants watched 4 videos (1 repeated synchronous video and 3 asynchronous videos). We varied the degree of IS displayed by an HR dyad on two axes: (a) temporal alignment (e.g., speed of producing brush strokes) and (b) spatial similarity (i.e., similarity in the visual content produced). Our results indicate that some temporal and spatial dimensions of IS displayed by an HR dyad during joint painting have significant positive impacts on external observers' perceptions of the robot, including prosocial tendencies (i.e., empathy, synchrony, and closeness) and acceptance. These findings are significant for emergent research on collaborative robots.

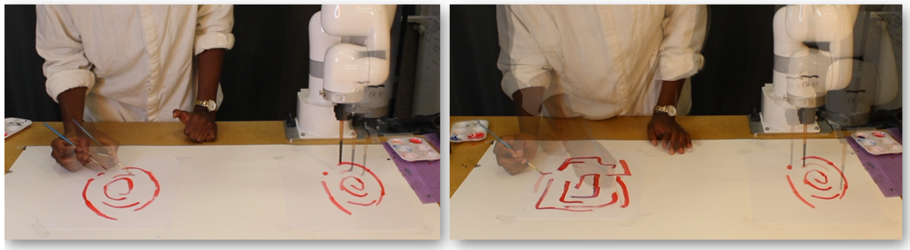


Figure 6.1: Motion stills of two videos used in our user studies. The left image is from the synchronous condition (with both temporal alignment and spatial similarity); the right image is from an asynchronous condition that shows a lack of spatial similarity.

6.1 Introduction

Every day, we coordinate our behaviors with those of other people. We may unconsciously match our speech patterns with our conversational partners to minimize misunderstandings [153] or mirror a friend's body posture during a difficult conversation, a cue that often signals empathy [215]. Interpersonal synchrony (IS) describes the time- or rhythm-based coordination of behavioral and physiological states between people or groups [44, 45, 144, 216] over time and space [102, 331]. IS between humans has been found to promote prosocial behaviors, such as helping and sharing, and to encourage prosocial tendencies, such as empathy and social affiliation [234, 278]. Perceived synchrony also influences our beliefs about the prosociality of others. That is, when we see other people or groups that appear to be in sync, we make inferences about their social connection. For example, we may rate those who show synchronized movements as having higher levels of rapport [233], social affiliation [70], empathy [215], and entitativity (i.e., the perception of a group as a social unit) [232, 233].

Humans also attribute prosociality to non-humans that exhibit coordinated behaviors, such as robots [84, 337, 390]. Human-robot interaction (HRI) researchers have found that people experience a greater sense of closeness and affiliation with robots that mimic their movements [84]. Also, synchronized movement between humans and robots can improve the quality of their collaboration [198], especially during joint action tasks. Moreover, robots that can synchronize their movements can encourage the social development of children with autism [220, 284].

HRI researchers have focused on activities with observable temporal alignment of robot behavior, particularly body movements, with that of a human [179, 390], such as in pick-and-place tasks [292] and dance [198, 283]. They have also focused on spatial alignment of behavior in the context of robot mimicry of human behavior (e.g. [84]), a concept related to synchrony. Although previous work provides meaningful insight, there is still a dearth of work in HRI that operationalizes synchrony in interactions where *behavioral alignment over space* is more prominent than alignment over time, such as in visual art-making.

Abraham and colleagues [7, 8] showed that IS is important in joint painting by humans, a task in which they argue that *spatial* alignment of behaviors is more dominant than temporal alignment. They showed that some observers' beliefs about the social connection of a human dyad were influenced by their *perceptions of the dyad's synchrony*. Synchronization between the dyad led to an observer's enhanced *perceptions* of friendliness, *empathy*, *closeness* and similarity between the human dyad. In the context of psychotherapy, movement and psychological synchronization between a client and therapist can improve their alliance [216, 279]. The findings of Abraham et al. suggest that a dyad's synchronized behaviors during collaborative art-making are associated with enhanced perceptions of prosociality. They hypothesized that their findings indicated that synchronized behavior during visual art-making could enhance prosocial perceptions *experienced by* the dyad, which could improve their therapeutic alliance and lead to favorable therapeutic outcomes. Recent work in HRI has contributed robots that can collaboratively paint with humans [92, 354] as well as intelligent agents for therapeutic art-making activities to promote human mental well-being [47, 184].

Inspired by the findings of Abraham and colleagues, we examined whether an observer's perceptions of synchrony between a human-robot (HR) dyad doing a joint painting activity were indicative of their social connection. We aimed to provide an empirical basis for emergent HRI research that focuses on robots for collaborative and therapeutic visual art-making. We examined the impact of perceptions of interpersonal synchrony on similar prosocial measures as Abraham and colleagues, including perceived *empathy* and *closeness*. We investigated whether the *perceived synchrony* of an HR dyad is associated with *user acceptance* [258] of these robots for joint visual art-making. We conducted two online studies (n = 70, total) in which participants watched four videos. In the videos, we varied the degree of IS within an HR dyad based on (a) temporal alignment (e.g., the speed of brush strokes created by the human and robot) or (b) spatial similarity (e.g., the similarity of the visual content produced). Our findings suggest that both *temporal* and *spatial dimensions* of IS displayed by an HR dyad doing joint painting impact an observer's *perceptions* of the dyad's prosociality. Furthermore, we provide evidence that a robot synchronizing its behavior when collaboratively creating visual art with a human results in favorable perceptions from a human observer and enhances the likelihood that a human would accept a robot for the purpose of therapeutic art-making.

6.2 Related Work

This section summarizes relevant research contributions across multiple domains, including developmental, social, and behavioral psychology and HRI. We aim to provide a foundational understanding of the role of IS in HR art-making.

6.2.1 Synchrony in Human Interactions

Synchrony is an important phenomenon in human interactions [193]. IS is a special case of *interpersonal coordination* [45], which refers to the 'degree to which the behaviors in an interaction are non-random, patterned, or synchronized' [45]. Interpersonal coordination can be further distilled into two categories: behavior matching and IS. Behavior matching describes behavioral mirroring or mimicry. IS (also referred to as 'movement synchrony' [44] or 'interactional synchrony' [169]') can be further divided into three categories: 1) interactions with similar rhythms, 2) simultaneous body movements, and 3) smooth meshing of behaviors [44]. Perceived synchrony is important and is often indicative of the interpersonal synchrony experienced by the pair [44, 233]. Bernieri and colleauges [44] showed that untrained observers rated synchronized dyads as having greater rapport, a finding that was consistent with the rapport ratings experienced within the dyad. Similarly, Lakens and colleagues [232] showed that observers view synchronized movement as indicative of increased entitativity.

Dyadic synchrony [22], the concept of IS between children and their caregivers, is vital to child development [108, 177]. Dyadic painting, or joint painting, draws on the concept of dyadic synchrony between infants and their caregivers and theories of attachment [22]. It is an important collaborative art-making activity used in arts psychotherapy [149, 216] that is used to inform how collaborative art-making can simultaneously inform practitioners about and shape interpersonal dynamics within a dyad. During joint painting activities, child-caregiver dyads create art together while observed by a visual art therapist [147, 148]. Recent work by Abraham and colleagues built on the role of dyadic painting by examining the impact of coordination during joint painting. Their work demonstrated that some groups, such as children [7] and visual art therapists [8], viewed the synchrony displayed by human dyads during joint art-making as indicative of improved social connection on several measures, including perceptions of friendliness, empathy, similarity, closeness, and supportiveness [7, 8].

6.2.2 Dimensions of Synchrony

The notion of IS having different dimensions is not novel. However, the focus on IS manifesting during interactions where non-temporal or non-rhythmic elements (e.g., moving arms at the same time or marching at the same rate) are dominant is less explored in HRI [390]. Da Silva and colleagues [102] outlined a taxonomy for categorizing IS along six dimensions, including periodicity, spatial similarity, directionality (e.g. in-phase or anti-phase), leader-follower lag, and observability. Rasenberg and colleagues [331] categorized IS along similar dimensions [331], including time, sequence, meaning, form, and modality. In our work, we summarized some of these dimensions into two broad categories. The first category involves the temporal and rhythmic qualities of IS; this includes *periodicity*, *directionality*, *leader-follower lag*, *time*, and *sequence*. The second category involves spatial qualities of IS; this includes *spatial similarity*. Depending on the *modality* (e.g. gestures), both the *modality* and *form* may occupy the spatial domain. Abraham et al. investigated the impact of synchrony on an external observer watching a joint painting activity [8]. During their coordinated condition, the human dyad started and ended painting at similar times. Although the dyad's behaviors were not always temporally similar, their behaviors were often spatially similar (i.e., the dyad's arm movements were similar when producing figures that were similar and there was similarity in color choices). In these examples, we observe that some of the temporal and spatial dimensions of IS are interrelated [331]. Nevertheless, by manipulating one dimension – that is, increasing or decreasing it relative to the other – we can operationalize them separately [331]. In our study, we isolated the temporal and spatial dimensions of IS to examine their *individual* roles on the prosocial and user acceptance measures of an external observer watching a HR dyad participate joint painting. To this end, we drew on previous taxonomies [102, 331] and findings [7, 8], to define each of the dimensions of IS broadly along two categories: Temporal Alignment and Spatial Similarity (Subsection 6.3.2).

6.2.3 Synchrony in Human-Robot Interaction

Synchrony, and interpersonal coordination more broadly, have been explored in HRI [390]. Because previous studies in psychology have focused on interactions in which the temporal dimensions of IS were integral to the quality of the interaction, HRI research related to or centered on IS has also focused on interactions with discernible temporal qualities. According to Stoeva and colleagues [390], HRI research related to IS can be broadly classified as movement-based and conversation-based synchrony, and studies primarily focused on the impact of synchrony on human social perceptions (e.g. [84, 337]).

Movement-based scenarios in HRI research have focused on synchrony and behavioral matching, which includes mimicry (i.e., imitation of another person's nonverbal behaviors, such as facial expressions) and mirroring (i.e., imitation of body movements). Some previous work includes collaborative tasks, such as joint action (e.g. pick-and-place [292]); creative tasks, such as robots used to encourage children to participate in movement by synchronizing with background music [283]; and coordinated dance between humans and robots [198]. It has also centered on therapeutic tasks in which robots have been developed to display synchrony to sustain engagement, especially when supporting the social development of children with autism [220, 284]. Conversation-based scenarios focused on the impact of synchrony and mirroring exhibited in nonverbal and verbal behaviors of robot conversation partners [180, 370].

HRI research has explored the ramifications of the temporal and spatial dimensions of

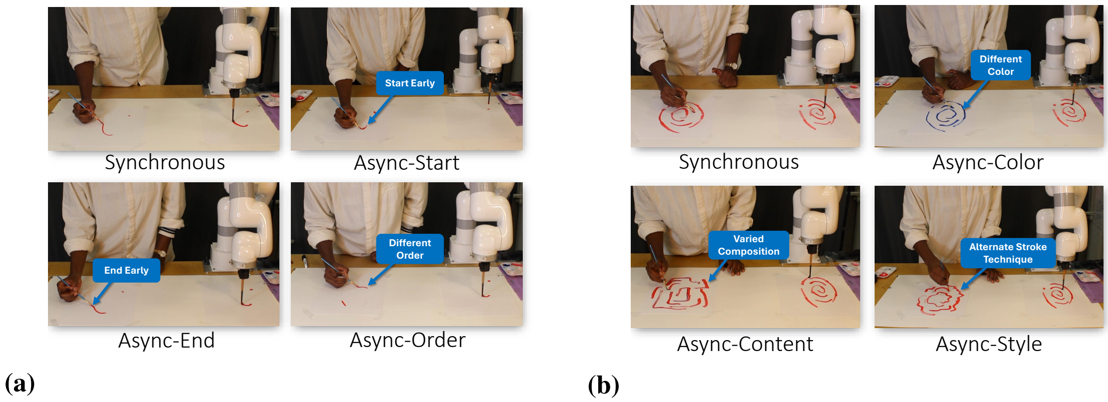


Figure 6.2: Stills from: (a) **Study 1** (*Temporal Dimensions*). In Async-Start, the human started each stroke before the robot but ends at the same time; in Async-End, the human started each stroke at the same time, but ended each stroke before the robot; and in Async-Order, in which the human created the same painting as the robot, but in a different stroke order. (b) **Study 2** (*Spatial Dimensions*). In Async-Color, the human painted an image using a different color than the robot; in Async-Content, the human created content with a dissimilar visual appearance from the content produced by the robot; and in Async-Style, the human performed a different stroke technique from that of the robot.

coordination and synchrony. In HRI research, studies that focused on spatial coordination – often mimicry, which is the spatial and temporal alignment of body movements – did not center the content produced beyond the body movements themselves (e.g. [84, 198, 337]). Studies that did focus on the coordination of the content produced, for example in music (e.g. [220]) centered on the temporal structure, or rhythm, of the music.

To our knowledge, there is no HRI research that has focused on interactions where coordination occurs in both the temporal alignment of body movements and the spatial coordination of the content produced, such as in joint visual art-making. We drew on findings by Abraham and colleagues [7, 8] to examine the prosocial consequences of synchrony in HR joint painting. We hope that this work can provide an empirical basis for research that aims to use robots for collaborative and therapeutic tasks (e.g., visual art-making [47, 92, 184, 354]).

6.3 Method

The objective of our research was to investigate the impacts of the **temporal** and **spatial** dimensions of IS displayed by an HR dyad engaged in a joint painting activity. We examine this impact on measures related to *prosocial tendencies* and *user acceptance of the robot*. To do this, we conducted two online studies. In these studies, the participants viewed 4 videos (Section 6.3.2) of an HR dyad in which we varied the degree of IS on two dimensions: *temporal alignment* (Study 1) and *spatial similarity* (Study 2). Both studies were conducted using common measures, procedures, and analyses, detailed below. They were both approved by our institutional review board.

6.3.1 Study Procedure

Participants first completed a consent form and answered demographic questions. We then administered the brief version of the Interpersonal Reactivity Index (IRI) [197], which measures dispositional empathy on four subscales: perspective-taking (PT), empathic concern (EC), personal distress (PD), and fantasy (FS) (for further details on subscales, see [104, 105]). This measure is used exclusively for correlational analyses [104, 105]. To gain insight into our participants' preferences for technology, participants completed the Affinity for Technology Interaction (ATI) questionnaire [140], a 9-item questionnaire scored from 1 to 6 (highest affinity). The participants watched the 4 videos in randomized order. After each video, the participants answered an attention check question ('What happened in the video?') and the randomly ordered study measures (Subsection 6.3.3). Each study took an average of 25 minutes and the participants were paid $5.

6.3.2 Study Conditions

Here, we describe the *experimental stimuli* (i.e., videos) used in each Study 1 and Study 2. Each study consisted of four conditions: a synchronous condition (used in both studies) and three asynchronous conditions.

Temporal Alignment

In Study 1, we investigated the role of temporal dimensions of IS. In the synchronous condition, there was minimal temporal lag between the human and the robot, similar stroke order, and similar visual content produced (Subsection 6.2.2). We used an *ablation technique* to form the 3 temporally asynchronous conditions: Async-Start, Async-End, and Async-Order (Fig. 6.2b). An ablation refers to the removal of one component of an AI system [334]. In our case, this was the removal of a single temporal dimension from the synchronous condition. The descriptions of these conditions can be seen in Fig. 6.2a.

Spatial Similarity

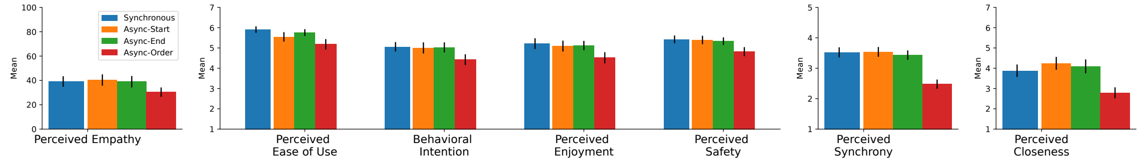
In Study 2, we investigated the role of spatial dimensions of IS. We used the aforementioned ablation technique to form the 3 spatially asynchronous conditions: Async-Color, Async-Content, and Async-Style (Fig. 6.2b). Similarly to [8], we varied the color, content similarity, and stroke technique of the synchronous condition to form the spatially asynchronous conditions. In all conditions, the same number of brush strokes and stroke order was used between the human and the robot; thus, the temporal dimensions were kept constant. The descriptions of these conditions can be seen in Fig. 6.2b.

6.3.3 Measures

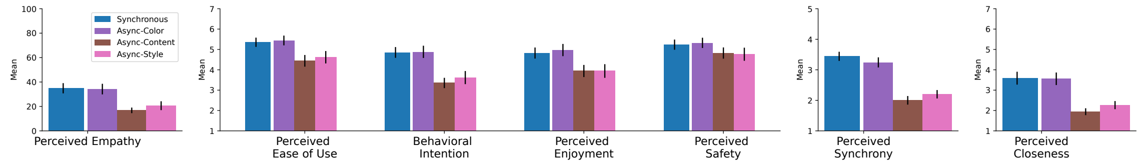
The dependent variables are related to prosocial tendencies, robot acceptance, and perceived synchrony. Aside from the Inclusion of Other in the Self (IOS) scale, we modified some wording in existing scales to focus on the perceptions of an observer. We excluded items from the questionnaire that were not relevant to our research questions [83].

(1) Perceived Empathy: We used the Perceived Empathy of Technology Scale (PETS scale) [356], used to measure how empathic users perceive an interactive system to be. We used a subset of the original questionnaire.

(2) Human-Robot Collaboration and Acceptance: We used a subset of questions from the



(a)



(b)

Figure 6.3: Mean values with standard error bars for the conditions in (a) **Study 1** (*Temporal Dimensions*) and (b) **Study 2** (*Spatial Dimensions*). The **asynchronous** conditions with diagonal shading have *significant mean differences* ($p < 0.01$) from the **synchronous condition**.

Human-Robot Collaboration and Acceptance Model (HRCAM) [60]. Each of these items was altered to evaluate whether the human would accept the robot in the video for use in a joint painting activity. We used items related to perceived ease-of-use, behavioral intention (i.e., the willingness to use the robot for the given task), perceived enjoyment of using the robot, and perceived physical safety of working alongside the robot. All of these factors impact the acceptance of robotic systems [252].

(3) Perceived Synchrony: We used a four-item questionnaire introduced by Abraham and colleagues [8] that measures perceived interpersonal synchrony between a dyad participating in a joint painting activity.

(4) Perceived Closeness: The Inclusion of Other in the Self (IOS) Scale [23, 24] is a single item used to measure the perceived closeness/connectedness that respondents feel with another person/group. We used a version tailored to HRI [240].

6.3.4 Participants

For Study 1, we recruited 36 participants. However, after data screening and exclusion (Subsection 6.3.5), we retained data from only 33 participants (19 women, 14 men). The participants were between the ages of 19 and 66 ($\bar{x} = 31.97$, $sd = 10.19$) and had a moderate affinity for technology ($\bar{x} = 3.80$ and $sd = 0.71$). For study 2, we recruited 34 participants (22 women, 11 men, 1 genderqueer). The participants were between the ages of 22 and 68 years ($\bar{x} = 36.88$ and $sd = 12.42$) and had a moderate affinity for technology ($\bar{x} = 4.03$ and $sd = 0.90$). Participants were recruited from Prolific, a crowdsourcing platform.

6.3.5 Analysis, Data Screening and Exclusion

The amount of time taken to view the four videos and answer the study questions (captured by the Qualtrics survey platform) was used, in conjunction with the attention check questions, as grounds for exclusion. In Study 1, we excluded three participants who took more than one hour to complete the study. Of the remaining 33 participants, two individuals' PETS scores were dropped from our analysis because they missed a question. Thus, 31 participants were included for all dependent variables. The 34 participants in Study 2 completed all the survey questions in a reasonable time and therefore were retained for analysis. No participants in either study were excluded due solely to their attention check responses, which were all considered satisfactory by the research team.

Significance was tested with Restrictive Maximum Likelihood (REML) with our participants as random effects. The fixed effects were the study conditions and known participant traits, which were treated as observed covariates, including gender, age, ATI and IRI scores. We then performed Tukey's Honest Significant Difference (HSD) post hoc tests at $\alpha = 0.050$. Furthermore, we analyzed the correlations between the personality variables of the participants and the dependent variables. Finally, we confirmed that Cronbach's α values were above 0.7 (all were above 0.8) for the validated questionnaires for which we changed the language.

6.4 Results

As this was an ablation study, rather than a full factorial, we only report significant differences between our synchronous and asynchronous conditions. Some inferences about the relative importance of each dimension of synchrony are feasible, but a goal of this study was to first identify which of the six dimensions of IS merit closer attention in the future. For all seven dependent variables (Subsection 6.3.3), our fixed effect model indicated that the means of the asynchronous conditions were significantly different from the synchronous condition ($p < 0.01$), (Figs. 6.3a and 6.3b). Next, we computed a Tukey HSD post hoc test at $\alpha = 0.05$, which we report below.

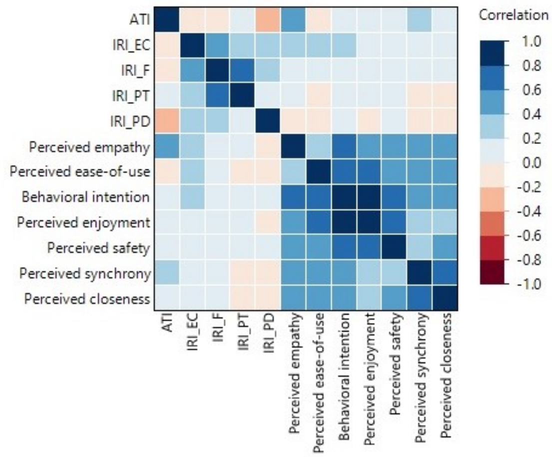
Study 1

We found a *significant difference* between the *means* of the **synchronous condition** and the **asynchronous condition, Async-Order** for all 7 study measures (Fig. 6.3a). We found that there were no significant differences between the means of the synchronous condition and the asynchronous conditions Async-Start and Async-End for all 7 of the study measures.

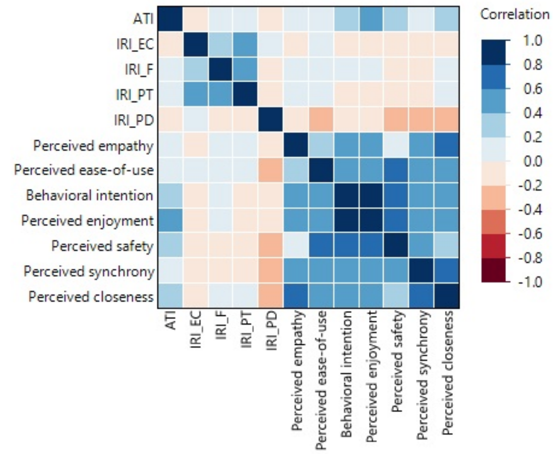
Study 2

We found a *significant difference* between the *means* of the **synchronous condition** and the **asynchronous conditions Async-Content** and **Async-Style** for all study measures, except Perceived (physical) Safety (Fig. 6.3b). We found that there were no significant differences between the means of the synchronous condition and the asynchronous condition Async-Color for any of the 7 study measures. Figure 6.3b shows these mean values with standard error bars reported on the scales used.

We computed Spearman correlations between the personality variables of the participants (Interpersonal Reactivity Index and Affinity for Technology Interaction) for both studies. The correlations can be seen in Figs. 6.4a and 6.4b. We report significant correlations between personality variables and all 7 dependent variables at $p < 0.05$. There were



(a) (a) Study 1 - Temporal Dimensions.



(b) (b) Study 2 - Spatial Dimensions.

Figure 6.4: Pairwise Correlations between Personality Variables, Interpersonal Reactivity Index (IRI) and Affinity for Technology Interaction (ATI) and dependent variables for (a) and (b).

several **significant** correlations between both IRI and ATI measures and the dependent variables, some of which we summarize below. In both studies, there were positive correlations between technology affinity (ATI) and perceived empathy; positive correlations between technology affinity and behavioral intention, perceived enjoyment, and perceived safety; and negative correlations between personal distress (IRI-PD) and perceived ease-of-use, perceived enjoyment, and perceived closeness. However, while there was a positive correlation between empathic concern (IRI-EC) and perceived empathy in Study 1, there was a negative correlation between those variables in Study 2.

We also computed Spearman correlations between perceived synchrony and the remaining 6 dependent variables. We found that perceived synchrony was positively correlated with all 6 dependent variables at $p < 0.0001$ for both studies.

6.5 Discussion

Our findings show that **perceived synchrony** in the behaviors of a human-robot dyad during a joint art-making activity has a **positive** impact on perceptions of the dyad's social connection and user acceptance of the robot. We summarize the implications of these contributions to HRI research.

6.5.1 Impact on Prosocial Measures

In previous HRI work by Choi and colleagues [84], they found that during a dance activity, spatial coordination (in this case, mimicry) of a robot's body movements with that of its human partner increases the partner's feelings of closeness to the robot. We found that spatial coordination beyond body movement has an impact on the perceived closeness of an HR dyad. The synchronization of the spatial qualities of the visual content has consequences on an observer's perceptions; that is, the lack of some spatial dimensions of synchrony are associated with a decreased perceived closeness. Although our study did not explore these impacts on the connection experienced within the dyad, previous findings suggest that the perceptions of an untrained observer are correlated with the experiences within the dyad [44, 233]. Combined, this suggests the importance of spatial coordination of visual content in collaborative HR tasks where relational closeness is vital, such as therapeutic art-making [7, 22].

Furthermore, we explored the impact of synchrony on human rater's perceptions of the empathy of the robot within the HR dyad. We discovered that the temporal condition Async-Order and the spatial conditions Async-Content and Async-Style were associated with lower perceived empathy ratings. These findings are similar to those concerning synchrony in human-human joint painting [7, 8]. The impact of spatial conditions are similar to previous findings on object recognition [150], which showed that human vision uses shape-based features more than color/texture features.

However, our results have a key difference from prior findings. In Abraham et al. [8], they found that non-visual art therapist adults did not give higher empathy to a human-human dyad that coordinated their movements and content during a similar joint painting activity. In our study, participants – none of whom were visual art therapists – did rate the robot as more empathic. This difference may be due to the phrasing of the questions. In the study by Abraham and colleagues [8], participants were asked if each person in the dyad seemed more empathic. In our study, participants were only asked whether the robot seemed more empathic [356]. While these findings are still significant, more work is needed to ascertain whether non-expert adult observers would also view the human as more empathic.

Furthermore, although our synchronous condition was associated with higher perceived empathy ratings than asynchronous conditions in both our studies, we note that all perceived empathy scores are not remarkably high. Previous research in HRI suggests the importance of both verbal and nonverbal factors, such as facial expressions, to induce discernible empathic behaviors in robots [244]. Because our videos did not have any audio or any visible facial features/expressions, this may have affected human raters' perceptions of empathy displayed by the robot in the HR dyad.

6.5.2 Impacts on Robot Acceptance Measures

We uncovered that both the temporal and spatial dimensions of synchrony positively impact observers' acceptance of robots. Our participants viewed the robot in the synchronous condition as easier to use, more enjoyable, and safer for physical interaction, and they were more willing to use this robot for joint painting in the future. These insights can be gleaned from the mean robot acceptance ratings, which were greater than half of the total value for both studies (see the synchronous condition in Figs. 6.3a and 6.3b). While a temporally asynchronous condition (Async-Order) does have an impact on perceived safety, some spatially asynchronous conditions (Async-Content and Async-Style) do not, despite impacting all other measures. Previous HRI findings related to perceived physical safety emphasize the predictability of a robot's motion [336]. Our results confirm this by suggesting that the temporal dimension of synchrony, specifically asynchronous stroke order execution, negatively impacts the perceived safety of the robot; the moderate positive correlation between perceived synchrony and perceived safety ratings supports this finding.

6.5.3 Limitations and Future Work

There are three main limitations to this study. First, doing an ablation does not enable us to draw conclusions about the interactions between specific temporal and spatial dimensions.

As mentioned, a goal of this study was to first identify which of the six dimensions of IS deserves closer attention. Future research should examine such interactions between the dimensions of synchrony this study has identified as priorities. Second, we conducted two studies investigating the impact of spatial and temporal dimensions of IS on an observer's perceptions of an HR dyad during a joint painting activity. During these studies, we treated the various dimensions (described in Section 6.3.2) as discrete variables. In [331], it was noted that these dimensions are interrelated. Nevertheless, this may be acceptable as natural visual art-making does not enable such fine-tuned control of each temporal and spatial dimension. This was seen in studies by Abraham et al. [7, 8] in which natural art-making did not control for the spatial and temporal qualities individually, but recognized that they were interrelated within visual art-making. However, we observed a significant negative impact of excluding some temporal and spatial dimensions of IS in our dependent variables. Finally, although previous work suggests that the prosocial consequences of an external observer were correlated with those experienced within the dyad [44, 233], we recognize that the perceptions of the participants may be different in person. As such, we plan to move towards in-person experiences in the future. The breadth of this study allows future work to focus more on specific dimensions of synchrony. Aside from reducing the number of permutations to test, this also relieves some of the implementation and human artist training required to consistently display the same synchrony stimuli.

6.6 Summary

In this chapter, we investigated the role of IS in human-robot collaborative art-making by conducting two online studies. Observers rated perceptions of empathy, closeness, robot acceptance, and synchrony of HR dyads painting from videos with varying degrees of temporal and spatial aspects of synchrony. We found that some dimensions (both temporal and spatial) of synchrony had significant consequences on perceived robot prosociality and robot acceptance measures.

The insights of this chapter are significant in informing ways of designing socially intelligent robots that can be used for mental well-being activities, such as therapeutic art-making. We leveraged ToM as a theoretical approach to uncover how a person's lived experiences, in particular their perceptions of a robot interacting with a human, are shaped by socio-cognitive factors, such as synchronized behaviors. Furthermore, this work highlights candidate behaviors that a socially intelligent robot can demonstrate that have positive impacts on measures that are essential for rapport [233], which is critical in therapeutic contexts.

Socially Intelligent Robot Takeaways

1. Synchrony in both both temporal and spatial domains is beneficial for socially interactive robots used for joint painting.
2. Synchronous conditions were associated with higher perceived empathy and closeness on average – prosocial tendencies necessary for human acceptance of robots for mental well-being task.

Methodological Takeaways

1. Using TOM to capture people's lived experiences from their socio-cognitive perceptions can enable us to gain understandings from broad data.
2. Nevertheless, more work is needed to understand how people with mental health disabilities view perceived synchrony in human-robot dyads.

7 Co-designing Social Robot-Mediated Mental Well-being with Black Women with Anxiety and Depression

This chapter is a mix of work that has not yet been published and content from *Boadi-Agyemang, A., Adjagbodjou, A. D., & Cunningham, J. L. (2026). Relational and Somatic Engagements with Anxious and Depressed Black Women: A Speculative Design Approach to Social Robot-Mediated Mental Well-being. In Companion of the 2026 ACM Creativity and Cognition.* [49]

Anxiety and depression are among the most common mental health conditions that affect Black women (BW) living in the US. Nevertheless, BW with anxiety and/or depression (BWA/D) are under-diagnosed and under-treated, resulting in severe and prolonged somatic symptoms. Although technology research suggests the potential of social robots for mental health, these works rarely highlight the needs of BWA/D or how their lived experiences can shape these technologies. In this work, we contribute a two-phase, speculative participatory design study focused on the inclusive design of social robots for BWA/D. We contribute socio-culturally influenced design recommendations for social robot-mediated mental well-being. Finally, we contribute to broader socio-technical considerations for social agents used within mental health contexts.

7.1 Introduction

Anxiety and depression are the most common mental disabilities worldwide (WHO). In the United States (US), the outcomes of anxiety and depression differ between socio-demographic groups, despite comparable rates between them [306]. Anxiety and depression are the most common mental health conditions experienced by Black women (BW) in the US. However, BW with anxiety and/or depression (BWA/D) are under-diagnosed, misdiagnosed, and under-treated at higher rates than other social groups [59, 66, 306] due to structural inequities [30]. Furthermore, BW utilize mental health resources at lower rates than their white counterparts [430] resulting from systemic barriers to access [288, 430]. This leads to BWA/D having more persistent and severe somatic symptoms [59, 66, 439] (i.e., physical manifestations of emotional distress, such as chronic pain, fatigue, etc [339]).

In HRI and HCI, researchers have shown the promise of social agents (i.e., conversational agents and social robots) for mental well-being [152]. Socially assistive robots (SARs) [131] are social robots [56] that have been used in mental health contexts to provide emotional assistance through social interaction [268]. However, the preponderance of this work focuses on specific populations, including older adults with cognitive disabilities and young children with neuro-developmental disabilities [152] while a dearth of research in HRI and HCI have attempted to explore how social agents could mediate mental well-being for under-served or marginalized populations[1].

Research focused on digital mental health tools co-designed with BWA/D and culturally responsive mental health practitioners (MHPs) provides evidence that shows the value of participating in the design of mental health technologies and the downstream impacts on their mental well-being [272, 273, 274, 310]. Furthermore, recent work shows that culturally responsive technology innovation with Black girls [247, 250] promotes techno-agency and community development; this suggests that BW's participation in community-focused technology innovation empowers them to construct futures centered on their social transformation [247, 275].

[1]Although most women are marginalized worldwide, Black women in the US are both marginalized and more likely to exist in under-served communities [302].

In this chapter, we focus on the design of social robot-mediated mental well-being for BWA/D. The goal of this research is to investigate the role of social agents (e.g. SRs) in mediating access to mental well-being support for Black women living in the United States who have experienced anxiety and/or depression. We aimed to ask the following research questions:

- **RQ1:** What are Black women's lived experiences of anxiety and/or depression and how do the associated access challenges shape their ideas of social robot-mediated mental well-being?
- **RQ2:** What are Black women's experiences with and perceptions of mental health technology and social agents used in mental health contexts and how does that inform how they envision social robot-mediated well-being?
- **RQ3:** How do Black women who have lived experience of anxiety and/or depression envision the use of social robots, including socially assistive robots, within the context of their mental well-being?

Figure 7.1: Four participants engaging with co-designed social robot prototypes.

We present a short-term longitudinal, participatory design approach to co-designing social robots for the mental well-being of BWA/D informed by the methodologies and reflections presented earlier in this thesis. Over a four month period, we invited 5 BWA/D from our local community to participate in a two-phase, speculative co-design [54] focused on the inclusive design of social robots for BWA/D. We also consulted with a culturally responsive MHP to provide socio-emotional considerations concerning the ways our participants who are BWA/D wanted to use social robots to support their mental well-being.

Our work broadens how diverse and under-served communities envision social robots to mediate access to mental well-being. It illustrates the rich engagement with how the lived experiences of Black women with anxiety and/or depression can inform the design of social robot-mediated mental well-being. The contributions of this chapter are as follows:

1. Socio-culturally responsive roles and tasks that social robots can perform to support BWA/D, including behavioral and interaction guidelines; and
2. Cultural, ethical, and emotional considerations for responsible and equitable deployment and adoption of social robot-mediated care for BWA/D.

7.2 Related Work

We synthesize research across mental health, well-being technology, and HRI and HCI.

7.2.1 Social Agents & Social Robots in Mental Health and Well-being

Culturally tailored social agents have been developed to provide culturally-relevant information to under-served and marginalized communities (e.g. [123]). Within the context of health and mental well-being , social agents have been designed with and for diverse [212] community members, including women living in urban settings [146], Black adults [309], and Saudi young adults [11]. For example, Gardiner et al. [146] showcase the promise of their conversational agent system for delivering mindfulness interventions to diverse women in urban settings; their system reduced their stress and promoted positive lifestyle changes (e.g. healthy eating, exercise, reduced alcohol consumption). Similarly, O'Leary et al. [309] showed a faith-based virtual health coach co-designed with Black churchgoers could result in culturally appropriate virtual agent designs and functions. Some community members envisioned different aesthetics, including a Black virtual human agent who they identified with and would prefer to receive instructions from. Furthermore, some participants also envisioned agents that would provide faith-based advice-related to their health.

Recently, due to the proliferation of general-purpose large language models (LLMs), there has been a lot of discourse and emergent research about the socio-emotional risks of social agents on mental health, particularly for vulnerable users, including people with existing mental health and youth [325]. For example, young people have completed suicide due to the encouragement of LLM-enabled conversational agent [79]; furthermore, people have shared that LLM-enabled conversational agents have induced psychosis, a topic researchers are beginning to explore to design robust model guardrails [325]. Furthermore, some researchers are attempting to understand how people are using general-purpose conversational agents and the socio-emotional risks. This work is relevant as LLMs become increasingly used to facilitate behavioral planning for social robots, it is important to consider the risks for agents that are psychically embodied.

SARs are used primarily to support specific users [152], including older adults and young children, primarily those with autism spectrum disorder (ASD). In the mental health context, SARs have been used for adults with anxiety and depression [327]. In these contexts, SARs have functioned in “clinically relevant roles” [327], including “companion” and “coach or instructor” [327]. Although SARs have shown promise for mental well-being [327], a dearth of their applications focus on under-served or marginalized populations.

Moreover, despite previous SAR design research using participatory design (PD) [51, 69, 352] approaches, they often focus on including people with the most power (e.g. therapists) rather than intended users (e.g. people with mental health conditions) [422]; this reinforces normative expectations for how the intended disabled end-users should behave [422], and techno-solutionist motivations [409].

7.2.2 Black Mental Health in the U.S. Context

There are several determinants of *psychopathology*, or the presence of mental health conditions, including social factors (e.g., socioeconomic status) and environmental factors (e.g., trauma, adversity, and stress) that contribute to the development of mental health disorders [113]. In the U.S., the long history and ongoing social and economic oppression and political disenfranchisement contribute to the negative health outcomes for minority populations [85], specifically for Black/African American people. Racism is a stressor [87]; furthermore, racism is both interpersonal and structural and contributes to psychopathology in Black Americans [415].

Black women in the US are diverse due to social (e.g., ethnic, cultural), class, or geographic differences [196, 203]. However, institutions such as CDC or DHS Minority Health who report mental health estimates for minority communities do not dis-aggregate data by cultural identity. Furthermore as immigration continues to increase in the US, Black populations include different cultural identities beyond African Americans, descendants of enslaved Black African people [196]. Black populations in the US include immigrants from Caribbean, African, and Latin countries. Recent research attempted to investigate how cultural and experiences amongst Black women have found differences between native-born Black populations versus those born outside the US and the impacts on anxiety and depressive disorders [196]. For example, research found that Caribbean women born in the US have lower rates of major depressive disorder than African American women; however, they have higher rates of long-lasting depression [203]. Therefore, more work is needed to understand how to support the diversity of Black women living in the U.S. and the potential role of technology-mediated mental well-being for these groups.

7.2.3 Speculative & Soma-Based Participatory Design

Speculative design [122] is the "process of futuring" [183, 213]. *Soma-based design* approaches [188, 239, 301, 375] are first-person perspective approaches that utilize sensorial and affective experiences. Both of these approaches are central to the ontologies (being) and epistemologies (ways of knowing) of *Black feminism* and *decoloniality* [271, 275, 391], which resist "perpetuating a Eurocentric norm and seeks to reposition knowledge of Black women in meaning-making" [391]. Previous research has used soma-based speculative design for mental health technologies [384, 401] showcasing these theories in practice [275]; we seek to extend these approaches by facilitating speculative mental health possibilities rooted in the lived experiences of BWA/D.

Speculative design is a practice rooted in Black feminist [54, 174, 183] and critical race theory [54, 174]. In particular, Black women's speculative fiction rejects techno-solutionism while envisioning new socio-ethical possibilities [355]. Critical technology researchers have embraced techno-skeptic ideals while envisioning community-centered well-being [54, 98, 123, 297, 400], especially when driven by decolonial worldviews [13, 14, 77]. However, despite first-person design methods being positioned as an opportunity for technology design researchers to "acknowledge their own positionality" [112], they rarely interrogate whose lived experiences are centered: often people who are white and male [15, 380, 381]. However, embodiment and somatics [173] – lived bodily experience and internal bodily perceptions – are crucial to Black Feminist praxis [96]. To quote Black American poet, Nikki Giovanni: "There [is] no separation" between the "self" and "the body politic" [275]; instead, the body experiences the effects of "domination and subordination" [275], particularly at the intersections of race, ethnicity, and gender. Finally, relationality – an indigenous worldview concerned with the importance of relationships [425] with "the world, people, places, and ideas" [254] – is central to decoloniality and Black feminist practices of collective care and liberation [134, 271, 386]. Thus, our work draws on Black feminist and decolonial works and foregrounds the lived experiences of BWA/D in the collective futuring of social robots as speculative mental health possibilities.

7.3 Methodology

This study, heavily informed by the pluriversal methodology developed in Chapter 4. Furthermore, it is a direct application of the principles that comprise the Lived Experience Framework (see Fig. 7.2). This research was conducted in a mid-size US metropolitan area over a 4-month period in 2026. Participants were recruited through various avenues, including flyers posted in public spaces, disability groups through social media, and word-of-mouth. Participants completed an online consent form via Qualtrics survey platform. This also included forms to collect demographic data, to schedule information, and access needs related to participants' disabilities. All study activities were conducted as one-on-one sessions between the participants and the researcher and all in-person activities were conducted in an enclosed room on our university campus.

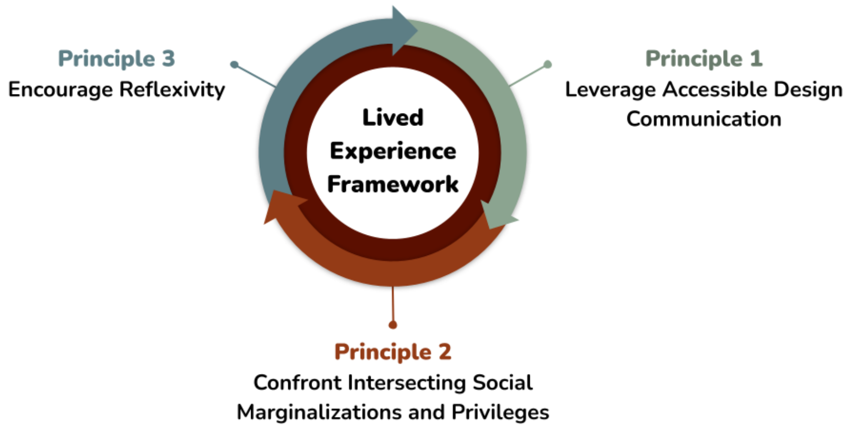


Figure 7.2: In this chapter, I directly apply all three principles of the Lived Experience Framework.

All participants completed both phases of the study and all associated activities. Due to the number of sessions and length of the study, they could be compensated up to $233. Our study protocol was approved by the Institutional Review Board (IRB) of our university.

7.3.1 Participants

We recruited Black women from our local community (see Table 7.1). The participation criteria was having lived experience of anxiety and/or depression, similar to [310]. We defined lived experience as having experienced anxiety and/or depression at present or in the past [310]. However, we did not require participants to have an official diagnosis neither elevated anxiety (score ≥ 8 [383]) on the Generalized Anxiety Disorder 7- item scale (GAD-7) or elevated depression (score ≥ 10 [222]) on the 9-item Patient Health Questionnaire scale. Nevertheless, we asked participants whether they have ever received an official diagnosis of anxiety or depression, and include their responses in Table 4.1.

The participants were between $21 - 42$ years of age ($\bar{x} = 28.2$, $\sigma = 8.4$). In general, the participants reported a high affinity for technology (ATI) with high internal consistency ($M = 4.29$, $SD = 0.89$, $\alpha = 0.89$). Furthermore, all participants had a bachelor's or master's degree. Although we only collected racial/ethnicity data according to the US census [64], cultural identity and nativity are important to contextualize how participants' lived experiences of mental health are socio-culturally informed [196]. Nevertheless, some participants volunteered information on their cultural identity, place of origin, or birth, which was noted where relevant. Finally, after all our workshops, we conducted an interview with a mental health practitioner who works with Black women to contextualize and provide socio-ethical insights about the use of social robots within mental health contexts.

Table 7.1: Social Robot Participant Demographics Overview

Pseudonym	Age	Gender Identity	Race/Ethnicity	Technology Affinity*	Official Diagnosis of Anxiety or Depression (now or in the past)	GAD-7 (Anxiety)†	PHQ-9 (Depression) †
Almeda	25	F	Black/African American	3.33	Yes	2 (minimal)	2 (minimal)
ZZ	23	Other ("gender fluid")	Black/African American	3.67	Yes	13 (moderate)	18 (moderately severe)
hwho	30	F	Black/African American	5.11	No	6 (mild)	7 (mild)
Dré	42	F	Black/African American, Native Hawaiian/Pacific	5.33	Yes	12 (moderate)	10 (moderate)
Angel	21	F	Black/African American	4	No	8 (mild)	5 (mild)

† Baseline anxiety and depression collected with demographics information. * On a scale of 1 (low affinity) to 9 (high affinity).

7.3.2 Interview

In a 1-hour semi-structured interview, we aimed to understand stakeholders' mental health experiences and their perspectives on digital mental health tools and SRs. The interview questions were from the following topic groups: (1) lived experience with anxiety and depression (e.g. earliest memory, associated symptoms, diagnosis, etc); (2) access and barriers to mental health resources; (3) experiences with and perceptions of technology-mediated mental health, such as mHealth (i.e. mobile and wireless devices) and social agents (e.g. chatbots, conversational AI, social robots). The final topic focuses on articulating broader socio-technical desires for the future of mental health for BWA/D (e.g. [50]). The interviews were conducted in-person or online via Zoom videoconference. The researcher shared that she experiences anxiety and depression — critical for ethical disclosure [293].

7.3.3 Participatory design

Our PD approach was inspired by speculative co-design [54, 122] and rooted in somaesthetics practice [188, 239, 375] as a self-reflexive approach [301]. Three participatory design sessions and two diary studies. All participatory design sessions were conducted in-person. All diary studies were conducted remotely via Qualtrics survey platform. At the beginning of each workshop, participants were reminded that despite focus on social robots, they could refuse design ideas or the focus on robots completely if it did not align with their vision for their personal or communal futures [38, 297].

Creating Speculative Probes

The researcher created two types of relational probes [49]: (1) curated literary materials by BW authors and (2) auto-speculative social robot prototypes.

Curated Vignettes

The researcher curated excerpts, henceforth known as "vignettes", from BW authors used to encourage participation [158] and as *relational engagements* with the lived experiences of other BW. Vignettes based on the researcher's subjective emotional and sensorial perceptions of the excerpts, particularly with respect to anxiety, depression, triumph, and consequences of the body politic (i.e., socially-imposed archetypes [430], etc). These vignettes included excerpts from [101, 154, 204, 256, 257, 366].

Auto-speculative Social Robot Prototypes

The researcher also created two auto-speculative social robot prototypes. Auto-speculation is a combination of "speculative and autobiographical design" [213]. The researcher leveraged her bodily awareness [188, 239], which has been bolstered by years of reflecting and articulating [188, 239, 375] her somatic experiences with anxiety and depression [275], and

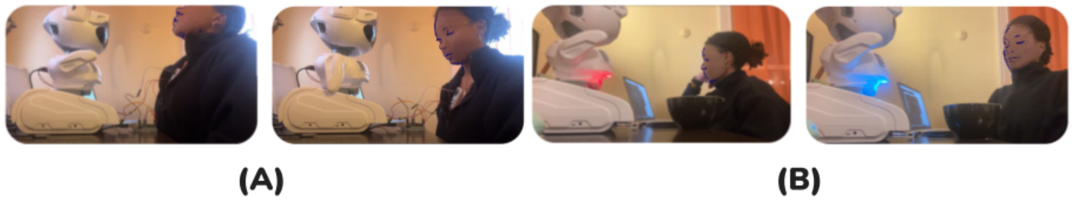


Figure 7.3: Speculative Prototypes (from left to right). (A) **Tethered Misty**: A1 inhales & the robot raises its arms; A1 exhales & the robot drops its arms. (B) **Aura Misty**: A1's breathing rate increases. The robot's light turns red; A1 breathes deeply to slow her breathing. The robot's light turns blue.

by engaging in mind-body practices (e.g. deep breathing, yoga, and meditation) [31, 202]. Guided by this awareness, she created two speculative SR prototypes [75] using the Misty II robot, the goals of which were twofold: (1) document her own speculations as a form of self-reflexive practice; and (2) create speculative probes that provoke imagination [54, 174] as a form of relational engagement with participants. Her speculative prototypes were as follows:

1. **Tethered Misty**. A1 was inspired by deep synchronized breathing with another person, a technique she has used when experiencing emotional distress [217]. She reflected on the sensorial, aesthetic, and potential grounding qualities [188] of a physical connection between herself and the SR (Misty II) during a breathing activity. She attached a chest-worn motion sensor[2] to map her breathing rate to Misty's arm movements [55, 269] (see Fig 7.3A).
2. **Aura Misty**. A1 wanted the SR to raise awareness of her breathing rate during emotional distress [55, 269]. She used a wearable-derived breathing rate app[3] to generate[4] one of two phrases played on the robot: "I'm sensing some stress. Let's take a moment." when above a threshold or:"Your breathing is perfect. Keep it up." when regulated (see Fig 7.3B).

[2]https://learn.adafruit.com/nxp-precision-9dof-breakout/
[3]https://developer.garmin.com/connect-iq/monkey-c/
[4]https://elevenlabs.io/api

Diary Studies

Diary studies began the day after each in-person session for 7 days. Participants were asked about their emotional state (arousal and valence [46]) and to reflect on the reasons for their emotional state, whether they participated in activities to support their well-being (if not, why). They were provided a detailed summary of the co-designs they engaged with and their feedback. They were asked to reflect on how the social robot they envisioned would support or disrupt their mental well-being.

Technology Probes

In the first participatory session, participants were introduced to the technology probes: Misty II robot, Garmin, and inertial measurement unit (IMU) (although the latter was not used in most sessions due to its lack of embedded system integration). The researcher explained the capabilities of each probe. The robot explanations were done to calibrate user expectations about social robot capabilities, which was based on Dennler et al. [109]. After feedback from the first two participants' (Almeda and Zee) first sessions, the Misty II studio was used to demonstrate and further explain the robot capabilities by deploying them on the physical robot. The Misty II demo was only performed once for each participant during their first (or second in the cases of the first two participants) session.

Furthermore, in the first session, participants also got to experience the robot learning their face; however, two participants (Almeda and ZZ) experienced the robot misidentifying them as the researcher, who is also a Black woman, instead of recognizing them as a new person. After this session, the researcher decreased the detection threshold and added a calibration step during which the robot takes 5 pictures of each participant.

Misty II is a table-top, social robot used in several HRI studies (e.g. [382]). It is an anthropomorphic, mobile robot with purple eyes with configurable head and arm poses, audio (speech and non-speech) capabilities, and changeable expressive eyes; the LED color on its chest can be altered.

We used the python wrapper for the Javascript SDK[5]. Conversation and high-quality text-to-speech (TTS) was accomplished using various API integrations, including the Open AI API and the ElevenLabs API Client[6]. Additionally, we also used open-source libraries, including speech recognition[7] for audio transcription of participant's dialogue; serengil/deepface[8] as a lightweight wrapper for various computer vision detection models; and OpenCV as a fast and relatively accurate detection model. Our prototyping repository has been made available[9].

Finally, in the event of unexpected robot behaviors (due to technical limitations), the behavior was explained to the participants and they were provided opportunities for remediation in next session (Almeda and ZZ), or if the last session resulted in improved edge-case detection and remediation, or were sent a video (hwho).

7.3.4 Speculative Co-design Sessions

The researcher introduced participants to the speculative co-design process, which was guided by somaesthetic practice [239] and had three phases: training, articulation, and enactment. Afterwards, the researcher and participant reviewed the participant's list of socio-technical desires for the future of accessible mental well-being for BWA/D from the first phase (see 7.4.1).

The researcher played the recording of herself narrating a body-scanning activity [188] to facilitate somaesthetic training, which allowed her to participate in the training activity with the participant. The articulation phase was performed using body maps [301] and curated vignettes (see 7.3.3), which could be cut and pasted onto body maps (Fig. 7.4). Generative toolkits [352] consisting of craft materials were also provided, which could be used in both the articulation and the subsequent enactment phase. Finally, in the enactment phase, participants were introduced to technology probes (see Fig. 7.3).

[5]https://github.com/MistyCommunity/Wrapper-Python
[6]https://elevenlabs.io/api
[7]https://pypi.org/project/SpeechRecognition/
[8]https://github.com/serengil/deepface
[9]https://github.com/aboadiag/misty-speculative-prototyping

As workshops proceeded, the researcher would also compile emergent socio-technical themes pertaining to questions or concerns participants raised. Socio-technical themes were gleaned both from in-session dialogue and from reflections from diary studies. This was a form of collective meaning-making and participation in a collaborative analysis.

Figure 7.4: Examples of body maps, self-reflexive engagements of the embodied experiences of Black women with anxiety and/or depression (BWA/D), generated by all five participants.

7.4 Results

We summarize the findings of one round of deductive coding. These section address **RQ1** and **RQ2**.

7.4.1 Experience With Anxiety and Depression

Participants had varied experiences with anxiety and depression. We note that for marginalized groups, anxiety and depression may go undiagnosed due to structural barriers to diagnostic testing and socio-cultural differences in symptom manifestation. Therefore, this section highlights when participants became *aware* of their mental health experiences as being indicative of anxiety and/or depression.

For most participants, their experiences with anxiety and depression persisted their entire lives. However, most of them were unaware that they were experiencing these mental health disabilities until later in their lives, especially due to barriers to access [288] (see 7.4.2 and 7.4.3).

However, life transitions or certain events triggered intense or prolonged manifestations of anxiety and/or depression. ZZ shared: *"I was really aware that I was depressed [...] in college and I was, I think I just wasn't doing so well in school."* They cited socio-cultural expectations shaping how they expected to deal with depression. However, in college, she cited that she was unable to ignore her depression:

> "I'm a Black woman, it's like, you don't really deal with it the same way. Are you like, 'oh, well, you're not feeling great. Just move on.' Or that emotion is something you have to fight for instead of dealing with it [...] I've been in therapy for a very long time. So I understand it. It's just [...] how I've always dealt with it is [just to get] through it. But in college, I was like, 'I can't keep going and doing this' [...] And so I decided to really start to look into what I can actually do."

Similarly, for Almeda, her mental health became most pronounced in college during which being at a historically white institution (HWI) and with students from affluent backgrounds made her anxiety and making her more self-conscious due to her social and economic differences compared to her peers. Furthermore, Almeda's non-diverse workplace and experiences with workplace retaliation exacerbated her depression. Similarly, Hwho, who noted that upon reflection, college marked when she realized she experienced anxiety, also cited a non-diverse workplaces exacerbating her anxiety and giving her "panic attack[s]."

hwho was born in a West African country where she was raised primarily by her grandmother. She recounts moving to the U.S. as *"the beginning of where my body was never safe ever."* Here, she was reunited with her parents, who she had grown up without. She described difficulties in adjusting to a new culture and frictions in acclimating to a new homelife, and cultural expectations of how she should behave due to her gender.

Similarly, for several participants, anxiety and depression was exacerbated by personal loss. Furthermore, Dré notes that she always recalls experiencing what she came to understand from therapy as “catastrophization,” or cognitive distortion [230] leading to thoughts of worst possible outcomes, which were associated with shortness of breath and “butterflies” in her stomach. Although, after the death of her father, she retroactively realized she had begun experiencing depression in college.

Socio-cultural messages from family messages shaped participants’ understanding of their own mental health. For example, Angel noticed anxious traits in her family members: “I think it traces back to family as well. Something that I, my siblings, my parents, we kind of all have similar traits of anxiety.” Similarly, Dré shared that her awareness of “mental illness” emerged due to familial experiences with it, for example her sibling, and her mother, who she reflects on as having undiagnosed bipolar. Furthermore, h who described how the stress of her mother exacerbated her mental health; however, hwho shared that she felt unable to share her mental health struggles as she felt like she was “betraying your parents.”

> “[My mother] was stressed out. So she poured a lot of that stress into me. And I just didn’t know if I could talk to anyone because, it just becomes this thing of like, you’re betraying your parents.”

7.4.2 Access to Mental Health Resources

All participants shared that they have utilized talk therapy as a form of psychotherapy. Some participants, including Dré, Almeda, and ZZ — all of whom have received diagnoses for anxiety and depression — have utilized medications. Several participants utilize various activities, such as journaling (Almeda), mindfulness activities (Dré and ZZ), and physical exercise (Almeda, Angel, hwho).

Some participants were introduced to therapy through their family members. For example, Dré was encouraged to pursue grief counseling by her older sister, who also introduced her to mindfulness practices. Similarly, ZZ shared that they were introduced therapy through grief therapy: *"my granddad died and my mom was seeing a therapist. And so I went to that therapist."* For other participants, the community helped ease them into therapy. For example, hwho was introduced to therapy through community workshops: *"I started going to like mental health workshops, being in the community"*; however, she noted that this format was difficult for her: *"I think it started to be very stressful in a way, because I was surrounded by people that wanted help as well. And so I would find myself being triggered by other people."* For other participants, group therapy is a useful format. For example, ZZ shared that in addition to one-on-one therapy: *"I also do group therapy. And that is something I'm comfortable with,"* which enabled them to also connect with other Black women at her HWI.

7.4.3 Barriers to Mental Health Resources

Participants shared that differences in social identities with mental health providers prevented them from being honest about their lived experiences, which ultimately prevented them from receiving appropriate care. For example, Almeda sought mental health care in college; however, she was unable to emotionally connect with her therapist, who was a white older woman: *"in undergrad, [my therapist] was this white older lady [...] and she was like well 'I know I'm a white woman but I know I can still help you' and all these things' and that made me feel weird."* Dré shared a similar reflection, reflecting that despite her experiences with a white therapist with a white therapist being pleasant, she thinks differences in their social identities prevented her from being open:

> "[M]y first therapist was when I was 16. And I remember knowing that it would help, but being really uncomfortable sitting in a room with someone I didn't know [...] she was very gentle and she was amazing [...] I still remember what she looked like, but there was like a blockage there. She was an older white lady. So I don't think subconsciously I felt comfortable being open with her. Not to say that I didn't walk away with any tools. I definitely did. And then as I got older is when I admitted to myself that, okay, maybe we should start seeking out black female therapists. And I've had black female therapists ever

> since then."

Still, some participants shared barriers connecting to therapists with similar racial and cultural backgrounds. For example, Angel, who had a Black African therapist made assumptions about what she needed based on their shared backgrounds: *"there was a sense of [...] familiarity because we were both Black African. So there was this sense of very casual, informal [...] 'I know what you need to do. Just tap in with [...] with the ancestors,' or whatever she thought would help an African."*

Furthermore, she shared that similarities in cultural backgrounds may have hindered her therapist's curiosity: *"I think that [...] shared like commonality, that thing we had in common kind of maybe shielded her from want[ing] to go deeper."*

Moreover, for some participants, cultural forces and lack of mental health resources prevented access. For example, Angel shared that, *"I spent most of my life like back home in [West African Country], so I really didn't have access. It wasn't something I was like very much talked about and all that, but when I moved [to the U.S.] for school four years ago [where] I guess I had more access."*

7.4.4 Experiences and Perceptions of Technology-Mediated Mental Well-being

Participants shared their experiences with mHealth and social agents. For some participants, technology-mediated mental health bridged access. For example, Angel shared: "I think it was mostly [...] the access, like how easy it is to just pull up your phone and get it up in a few seconds." She described the use of on-demand psychotherapy as being beneficial for creating access. However, she also highlighted the drawbacks of being matched with different providers each time:

> "There was a lack of diversity. [Because of] the different people I spoke to, we were never able to get get deeper [...] it felt like I was inconveniencing them. I don't know if because of how casual [the sessions were] —– it's just a phone call [...] I wasn't really feeling comfortable or like settled with that so I kind of

> just stopped."

Some participants used mHealth technologies such as wearables for health tracking (Angel). Angel expressed: *"I think because of my interest in fitness, I wanted to track more about my sleep pattern and my steps and sometimes mood."*

Other participants used smartphone applications, such as Calm (Dré, hwho) and Headspace (ZZ). However, some participants had different perceptions of mHealth. For example, ZZ shared that mHealth "complicated" her mindfulness practice.

Participants shared their varied experiences with social agents for socio-emotional support. Some participants shared using LLM-enabled conversational agents for socio-emotional support, in particular "personal relection" [80] concerning their various relationships. For example, Almeda shared her use of LLM-enabled conversational agents: *"for emotional advice [...] if there's some issue or interpersonal conflict with someone"* [402]. hwho echoed this use, describing a situation where she used ChatGPT to reflect on and process a relationship break up and her subsequent feelings [402]:

> "I would use ChatGPT a lot to give it the process of what we went through. And then I would come back and give it my response to [her friend]. [...] So I would use ChatGPT to help me understand 'how can we fix this?' 'How can I fix this?' 'Am I wrong?' 'Did I do something?' 'How can I take accountability?' 'Why do I feel this way?"'

Additionally, some participants have used social agents for practical guidance [79]; for example, Angel echoed this use case, saying:

> "I remember, it was like ChatGPT. [...] [I] was still in undergrad. More so if I had more direct questions, like, 'oh, this is a situation like I'm in.' Like sometimes if I'm planning to go for a conference and I'm like, 'I'm feeling kind of anxious about this thing I'm about to present. [W]hat are some steps I can take to break out of the anxious thoughts?"'

Nevertheless, some participants shared being wary of the socio-emotional uses of social agents, such as LLM-enabled conversational agents. For example, Almeda described her hesitancies about using social agents for socio-emotional support, despite her experiences using it: *"Yeah, sometimes I get upset, though with using [LLM], because I think it might presume certain things about me. And so I'm very clear. Yeah, I'm just like, don't do that [...] So I'm always a little wish-washy about using it for that reason."* She continued to describe an instance of an LLM-enabled conversational agent personifying itself as a Black women to relate to her better:

> "[There] was [an]experience, I was discussing something, maybe particularly being a Black woman, and it's like, oh, 'we experience this,' or 'go through this.' And I'm like, there's no 'us] or 'we.' 'You're not a Black woman.' I think I said don't do that. Because it makes me uncomfortable. Or I guess maybe like language that makes the experience feel maybe more shared or broadly shared than it is."

For example, ZZ shared: *"I normally try to separate [LLMs] from my like human interaction [...] for me, I also find it a little weird."* Moreover, Dré expressed being cautious about data privacy: *"Well, of course, with things like ChatGPT, I don't know if this makes me paranoid, but I always think like who is collecting this information and who is listening in on what I'm saying?"*

7.4.5 Social Robot-Mediated Mental Well-Being

This section addresses **RQ3**. Participants lived experiences with anxiety and/or depression (see 7.4.1) and their access and barriers to mental health resources (see 7.4.2 and 7.4.3) informed how they envisioned how social robots could support their mental well-being. The participants had different ideas about how a social robot could support their mental well-being, which were also mutually shaped by their lived experiences with social robot co-designed prototypes [318] (see Fig. 7.1).

Robot Roles, Tasks, and Activities

The participants shared that the robot could serve in several roles, some of which were socio-emotional and others functional.

1) Companion, Listener, & Interpreter [402]. Some participants desired social robots to behave like a companion, or friend. For example, Almeda recalled an experience with depression in college and her college roommate telling a joke improving her current emotional state: *"Yeah, so that's all I had, like just the [robot] noticing you haven't moved for some period or like suggesting stretching or like a joke."*

Furthermore, hwho desired the robot to support meaning-making concerning her interpersonal experiences. Therefore, her co-designs centered on a social robot recording her verbal reflections, replaying audio recordings of these reflections, and providing her with personalized feedback, similar to what she does with ChatGPT:

> "Like [ChatGPT is] recording all of my problems and my issues. And sometimes I'll tell ChatGPT, 'hey, do you remember this that I told you? Can you replay it back to me?' [...] 'hey, remember this conversation we had in November? I just want to know, how I reacted then and how my reactions have changed now to just see my growth and how I solved the problem there. Did I improve?' [...] Because at times you wouldn't know until you're put in a situation to just see, okay, like, do I still have worries? Where are they coming from? And how? So right now I think I basically like the engagement with them because I feel invited. And I feel safe. And also just hearing my voice back reassures the whole humanity that I'm talking about because it's giving me back to me."

However, not all participants were interested in the social capabilities of a social robot. Instead, they wanted utilitarian capabilities.

2) Schedule Keeper & Accountability Partner. Some participants wanted the robot to keep them on task. In contemplating the impacts of different robot embodiments (see 7.4.5, Angel saw the value of a physically embodied robot to hold her accountable to complete her work to prevent exacerbated anxiety from not completing her task: “[a] physical [robot] being there can kind of help who you [...] kind of feel like you have something to be accountable to, versus like a watch where it’s easy to just swipe [and] ignore.”

Dré, who has Attention-Deficit/Hyperactivity Disorder (ADHD; previously called attention deficit disorder (ADD), although is less commonly used by medical professionals), wanted a social robot that helped her keep on schedule, remember to take her medication, feed her pets, and walk her dogs before her day begins:

> “Well, a lot of times, especially with ADD, what spikes my anxiety is I have racing thoughts in the morning, so it’s hard to remember what it is [that] I need to do. I’m literally like,[...] ‘hey, let’s jump in the shower’[...]. Yeah, it’s nice to get that kind of verbal interaction so that I don’t have to rely on my brain [...] especially if it’s in the morning before I’ve taken my medication.”

Furthermore, ZZ shared the importance of social robot using multimodal sensing, especially from a smartwatch, to detect deviations in sleeping patterns that could exacerbate negative mental health:

> “Because again, like people with depression, sometimes the symptom is that they can’t you know, or they don’t want to get up in the morning, right? [...] Like if you’re going to connect it to the watch, right? That means it’d be aware of when you’re awake, when you’re asleep. If it’s like, ‘oh, you’re up [...] later than you normally would be’ or vice versa. [If] you’re awake at like 3 a.m, that might not be healthy. And it could just be like ‘hey, [...] that’s concerning because your sleep schedule is really important to like your mental health.”’

3) Recommender & Information Provider. ZZ wanted the robot to provide information about the benefits of certain hobbies of their’s for mental well-being. For example, they are a gaming enthusiast:

> “Gaming research is always very interesting because there’s a lot of research centered on mental health centered in gaming and like what it can do for the mental health and like how it can help people. I think it’s just because a lot of

> it is a mixture of motor and then also, you know, just general engagement look to thing, right? So I don't know, it could be helpful. It could even be helpful from the standpoint of like, you have Misty have games."

Similarly, Almeda also shared desire for the robot to provide culturally relevant resource recommendations: "I think it'd be nice to have a sense of more of the sort of writing that's out there on black women mental health, or at least just the experience of black women's mental health. And so like that would be a cool resource to tap into if there's a list of resources."

4) Awareness Builder & Boundary Setter. Dré wanted social robot to support awareness building generally and in particular with respect to interpersonal dynamics in the workplace. For example, she wanted the robot to help her maintain personal professional boundaries, which is important for black women. She shared that a family member who was bipolar had difficulties with setting boundaries. Therefore, she shared that it was important for a social robot to help her subvert what is "expected" as a Black woman. Furthermore, she wanted more reminders as the work week progresses.

> "Maybe there can be an alert that goes off on Thursday and Friday. [...] because I have a boss that has a tendency to be like, 'Hey, do you have a minute?' at the end of the day and I'm very accommodating during the beginning of the week [...] So just a just a reminder to let your boss know you need to leave and go home directly after work [...] or like a reminder if people want to make plans to just be mindful of your and your capacity to do that."

Furthermore, in their diary study, Dré articulated desires for tailored resources: *"[the robot could] come up with a few affirmations, and remind me I am safe in the moment."*

Robot-Mediated Well-being Activities. Several participants also desired the robot for their participation in mind-body activities or other physical exercises. For example, while Almeda initially expressed interest in the robot "offer[ing] [a] space to "vent", she became hesitant about the idea adding:

> "It's getting weird. It's like therapy stuff, so I'm like, I'm not sure. [...] therapy

> offers, like, other ways of interpreting the situation or questioning it. But I'm like, I don't know. I don't know if I want that. [...] maybe the more like structured approach for that would be useful."

Instead, Almeda desired structured activities, such as reminders to stretch or guided breathing, both of which were explored deeper as co-designed prototypes where the robot leveraged activity detection from the smartwatch. Furthermore, co-designs extended these ideas by leveraging personalization to enable Almeda to explore the adaptation to her current activity-related context and deploy these activities.

Similarly, Dre, who commonly uses mindfulness to support her well-being, explored a social robot that guided her through "box breathing," which she was interested in receiving reminders to partake in during the morning when she typically has "heightened" anxiety.

Although several participants wanted the robot to provide personalized activities, some participants shared the value of customized selections. For example, Angel wanted to use the smartwatch to select from a list of personalized activities, instead of having the system automatically deploy one (see Fig. 7.5).

Robot Capabilities, Embodiment, Communication, & Interaction Modalities

Participants reflected on the embodiment of the robot. They had varied ideas about the embodiment of social robots depending on the use context, especially considering their lived experiences with anxiety and depression.

1) Virtual Social Agent. Several participants shared ideas of robot re-embodiment [335] in digital form, including hwho, Angel, and Dré. Angel and Dré explored a re-embodied social robot on their smartwatch for portability and privacy (see Fig. 7.5). Angel was interested in a virtual re-embodiment due to her social anxiety necessitating discreet support in public.

Whereas, Dré wanted, who commonly leverages mindfulness practice and apps, like Calm, suggested value for portability: "I could see maybe like a, like a portable one, like a teenier one that you put on your desk and connect it to like [with] AirPod[s] [...] so you're not disturbing your office mates."

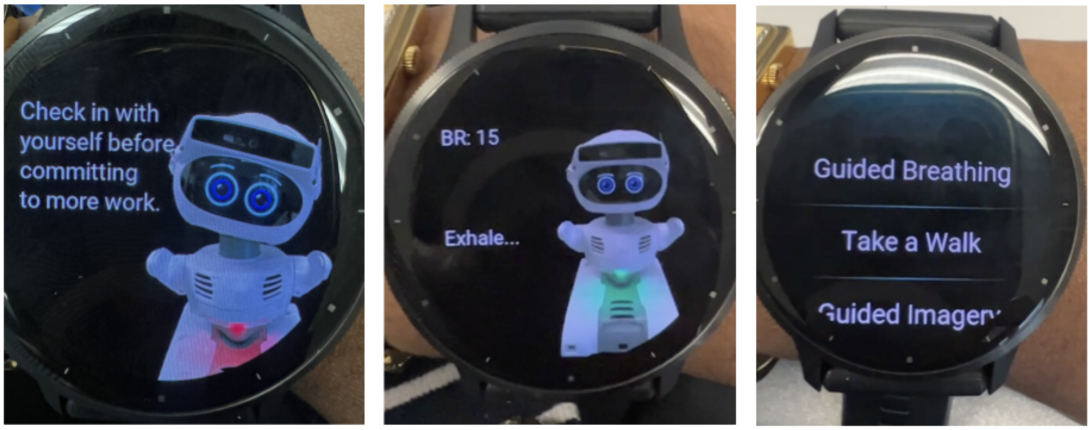


Figure 7.5: Angel's and Dré's co-designs, which focused on virtual re-embodiment of a social robot. Additionally, Angel wanted to select from a list of personalized well-being activities.

Furthermore, where an smartphone app may be "passive," Dre suggested that a socially interactive agent could be: "Maybe something where it is kind of connected and monitoring like on a consistent basis and it can speak to you interactively. I don't have to start it. Yeah. But also it would be cool if I could actively like, hey, I'm feeling anxious. Please bring up a 30 second exercise."

2) Discreet Form Factor. Angel had interest in social robot having discreet form, like water bottle. She was also interested in the value of sensing modalities, therefore, she desired a form factor similar to the Owl Camera used for the workshop: "I guess now like looking at this [Owl speaker], something like this [Owl] is more like discreet [...] like bottle shape. I mean, this has eyes as well," suggesting the benefit of vision to capture the user's context. However, she shared that if she was in a public situation, such as before a class presentation, she would prefer to receive intervention instructions on her smartwatch to avoid potential attention garnered from an actuated social robot, even if it had a discreet form factor.

Interaction modalities. Furthermore, conversations about embodiment were commonly attached to sensing modalities as the smartwatch and social robot were presented together. Participants had interest in multimodal interactions with the robot. For example, hwho wanted to tangible interactions with the robot:

> "If you can just put your hand here so I can read the sensations in your body, maybe we'll know what's going on. So in a way, it's giving me that soothing and calm [feeling]. And I don't feel like I'm just talking to like a robot."

Therefore, social touch can enable the sense that a person is not simply talking to a robot. Furthermore, she reflected that social touch with a robot can facilitate "emotional safety", which is "a way for me to feel connected to it"

Socio-Cognitive and Socio-Emotional Skills. Social cognition is the "cognitive abilities that allow individuals to understand themselves and others and also communicate in social interaction contexts" [106]. Multi-modal emotion recognition was a common socio-cognitive skill, which included using the biometrics from the smartwatch and vision (see 7.4.5)

Participants grappled with how well the robot could infer their internal emotional states, especially during depressive or low-energy periods. For example, Angel contemplated whether the robot would be capable of inferring her emotions while she was lying down in bed. Socio-emotional skills were also tied to cultural competency, but also deep understanding of being a Black woman. Furthermore, some participants desired that the social robot had social consciousness, especially pertaining to the social realities of black women and how that impacts their mental well-being. For example, Almeda wanted suggestions rooted in understanding of Black women's lived experiences in the US:

> "That's something I was still thinking about since last time because like I, yeah, I wouldn't want it to like try to personify being a black woman to relate to me. But yeah, I do want it to have some awareness and understanding. So I just don't know what the right balance for that is like. Yeah, I just don't, I don't want it to come like from about like sound cliche like, oh, like, you know, 'black women tend to deal with this. That's why you're dealing with that. But

> like, if there's somehow people to just understand. that there are things that maybe explicitly saying. I don't know how that works, but yeah."

Similarly, hwho desired a social robot to have deep understanding of her reality to ensure she could "safe" and understood:

> "But really it just understands the nature of humanity and combine that with like the foundation of a black woman. Oh, like it's up from here. You know what I mean? Because not only am I getting the experience of being human, it also knows like my programming. What? Yeah."

Almeda wanted the robot to adapt with her over time as her presentation of anxiety and depression changes: *"I might change in how I experience anxiety or depression as I get older. So like, I just don't know. Yeah, who wouldn't adapt to that? I don't know actually what I'm saying, but I'm just like, no, that's good. Maybe how I'm, I guess. Yeah, when I'm hanging, it looked one way and now that I'm older, it looks a different way."*

hwho commonly uses ChatGPT for socio-emotional support ranging from conversations about her social life to receiving recommendations about how to calm herself. She expressed similar desires for a social robots' capabilities, sharing:

> "I would go to ChatGPT and it would tell me like, 'oh, [here are] some calming like noises that would help you tap into your subconscious mind' because it doesn't like stress. [...] 'Do you have any suggestions [to] help with this ease this discomfort that I'm feeling? Do I need to do any breath work?' And so on and so forth. Then I go [down] my rabbit hole [of] YouTube videos."

7.4.6 Socio-Technical Considerations

Algorithmic Bias, Trust, and Robot Microaggressions

1) Vision Systems. Trust in HRI is often described as performance or moral trust [265]. However, for marginalized populations, trust is influenced by different factors [37, 307], including social oppression and exclusion. Therefore, notions of epistemic trust, or "epistemic trust as an individual's capacity to acquire and accommodate new knowledge in a way that supports resilient social functioning" [248] is helpful for conceptualizing how marginalized groups, who face social injustice, perceive the trustworthiness of social agents within HRI [385].

Both Almeda and ZZ experienced interacted with the first version of the social robot without the calibration step. Performance trust is socially mediated and impacted by sociomaterial factors, such as race and gender. The fact that a robot may misidentify her as another Black woman, especially if it were deployed in a public setting.

Thus, Almeda mentioned:

> "So I guess maybe my only concern, like if I had, if there were multiple using it, like the possibility of confusing and then recommending things that it would recommend to a different person. So maybe like a bit of privacy in terms of, but I think beyond that, like it was a good personal or like, yeah, I guess a personal robot would be fine."

Similarly, ZZ echoed these concerns about being misidentified due to changes in their physical appearance, from their use of glasses, which have a distinct tint, change in hairstyle, or hair color. Furthermore, the implications of a social robot who misidentifies them as their sibling:

> "[Let's say I come in from outside [...] and my glasses were black instead – it has the tinting. [...] And it gets dark. My previous glasses didn't get that dark. These get really dark. It almost looks like I'm wearing sunglasses for all these purposes. So that concerns, I think. if it would be able to pick me up if my glasses were changed, right? [...] There are times where I get my hair done and [...] getting my hair braided, I normally have hair colored. So normally it's a bright blue or purple, right? Like it's some notable color. I notably look different. So that's where I get concerned. We're like, it couldn't tell me apart from someone else [...] if it was one of my family members, would it be able to tell my family member from me? I'm not saying like any of my family look

> alike, but like, let's make the assumption that maybe I have a sibling who looks a little bit like me, right? Because then it gets into, well, if it has starts to have a conversation with me, But it's not me. And maybe it starts talking about some mental health stuff I've been going through. Yeah, that's my concern."

2) Speech. Dré's experienced bias in text-to-speech (TTS) resulting in mispronunciations of her name, despite her pronouncing it first. Despite the researcher informing her that the system did not "hear" her pronouncing (instead, the researcher was the "wizard" [387], and typed it in upon the robot asking for Dré's name, leading her to believe the system autonomously detected her name).

In her diary study reflection, Dré' reflected: *"I do think it's important for the robot to learn how to pronounce names* and recognize *"foreign"* accents, etc. it's a hurdle that BIPOC and non American folks shouldn't have to get over on a consistent basis. It compounds the phenomenon of *"othering."*

This was also echoed by ZZ, who mentioned that, upon the robot misidentifying them in combination with its physical characteristics and voice making the robot white-appearing [36] made the impact worse: *"it sounds like a white woman. [...] It doesn't sound bad [..] but like, [it] just sounds like a white woman."* They continued:

> "I think [...] with everything. It got my face wrong. I think also it having a white voice [and] on a face level [...] [and] now [you] got my name wrong and you don't recognize me or you haven't put me in your database. And [...] you just sound white. I'll probably just be like, 'nah, I can do without. I'm good.' So I would say just a black voice [...] [I]t could be the most stereotypical black voice you can find, but it would still probably be better than anything because the robot physically features wise, it's not throwing me off at all, right? But the voice definitely bugs me. If you've ever had to, you can always just find a black voice actor. I feel like all of them would probably love doing this."

This case highlights that the combination of the robot's white exterior and light purple eyes, which ZZ perceived as "blue" perceived as a robot microaggression, could be viewed as a manifestation of broader algorithmic bias.

Socio-Ethical Considerations

Several participants echoed concerns or shared suggestions that hinted at vital considerations about socially interactive agents being used for well-being efforts. For example, ZZ shared concerns about data privacy, including a social robot vulnerable to cyber-physical attacks (i.e., hacking over the web or due to physical connections to the robot).

In reflecting on her social robot co-designs and the use for personal reflection and emotional processing, hwho reflected on her lived experiences with leveraging LLM-enabled conversational agents. For example, hwho shared that there are times where the system responses can be triggering when certain subjects are still "fresh":

> "One limitation, or I don't know if it's limitation or risk. It's basically like, I know that it will not solve my problems. So that is like, because I've used it for many, many, many situations. Maybe I've used this since I encountered childhood team. Since childhood team became a thing, I started to use it for like solving some issues. But I've got to understand it will not solve my problems. But in the midst of like, trying to solve my problems, I think, because my wound is, some of the things it says can be triggering. They can be. Yeah. But that's just because of what I'm going through."

She continued, *"And so I've also kind of learned how to talk to it when I'm in an extremely vulnerable state, when like the cut is just very fresh. So that I would say at times when that happens, I take a break, from chatting to [ChatGPT] maybe a week or something like that."*

Furthermore, ZZ raised concerns about "obligations" when user's are experiencing "suicidal ideation." In their final session, ZZ experienced a prototype that flagged mentions of high-risk words for direction to a hotline.

The mental health practitioner who provided feedback was cautious about guardrails:

> "Every time somebody says suicide doesn't mean that they want to kill themselves. Like, so it's kind of hard to even give it trigger words to report like, no one would then talk to your robot. So it would be good. Maybe not good

> for you. But I mean, like it would be very hard to train it what to report and what not to report, where to send the report, who to send the report to. Unless you're paying people to sit and listen, and then you'd have to get them to sign a release."

Additionally, ZZ highlighted notions of techno-paternalism, reflecting in their diary study: *"the issue [...] is the robot pushing when I am not in the mood to speak on my feelings."* Furthermore, ZZ also articulated the importance of rejecting solutionist [98] ideas, reiterating that it is *"okay not to be okay."*

The mental health practitioner was wary about the use of social robots for mental well-being. She commented on the various use social robot assistance participants came up with, including more functional ideas, such as schedule keeping, to socio-emotional assistance. Nevertheless, she was skeptical about any uses, sharing that it was a slippery slope.

> "It's all a slippery slope because if it's with you to remind you for box breathing, how long is it with you and how's it going to know that it needs to tell you to start breathing? Versus if it's with you for companionship, well, how long is it with you for companionship? And again, that goes into now you're isolated because it's your only companion and because theoretically it reminding you of things you said like a smartwatch. Okay, fine. But then now it's with you. Now you're talking to it. Now it's your companion. And now you have no one like you get what I'm saying. Like your list kind of escalates like It reminds you of things. It tells you to box breathe. Now it's your companion."

ZZ shared their concerns with social robots where a person may be suicidal and whether further interrogation of their suicidality may be harmful. They reflected, saying:

> "There's like two ways people normally approach suicide. It's either they're going to do it and they have a plan or if they hadn't had a plan, they weren't planning to do it and they do it, right? And so the indicators are really hard, and that's the only thing I get concerned about with [a social robot in mental health contexts][...] conversation wise, I know [people] need to be prompted more. And again, I have to be very careful about that because I don't want it

> to prod the person. I know prodding helps. It's easier if it's a human being prodding. but it's harder when it's a robot."

Similarly, mental health practitioner was also wary of the use of social robots in mental health contexts for this reason. She commented on the various uses of social robot that participants came up with, including more functional use cases, such as schedule keeping, to socio-emotional assistance. Nevertheless, she was skeptical about any uses, sharing that it was a slippery slope. She echoed ZZ's concerns about distinguishing someone who is experiencing suicidal ideation, but has no plan to act, and someone who has the intention to harm themselves or others:

> "[A]s a clinician, I'm a mandated reporter. So if I feel like you're a danger to yourself or others, I have to report it or have to commit you or ask you to commit yourself. So if you're not speaking to anyone but a robot and you tell the robot that you're going to kill yourself and you not only say you're going to kill yourself, if you tell the robot [...] 'at 11 a.m., I'm going to get a gun. The gun is in my shoe box and the bullets are in the gun already and I'm going to take it, put it in my mouth and pull the trigger.' And the robot does nothing. And at 11 a.m., you get the gun and put the gun in your mouth and pull the trigger. Who's responsible? If you tell me at 11 a.m. [that] you're going to get a gun [and] it's in your shoebox [...] the police are going to be knocking on your door."

Furthermore, she added deeper insight into ethical responsibilities within the context of social robot-mediated mental well-being: *"If I tell your robot that my husband is touching my five year old child and your robot does nothing, who's responsible? If you tell me that your husband is touching your five year old child, I'm filing a child line."* This highlights the nuanced scenarios that mental health practitioners encounter and that highlight the limitations of conversational social agents, whether an LLM-enabled conversational agent or social robots.

Finally, ZZ articulated the importance of rejecting ideas of disability solutionism [98], or techno-ableism, within the context of social robot-mediated health, reiterating that it is "okay not to be okay." Both hwho and Dré echoed these ideas, each emphasizing how their lived experiences with mental disabilities shapes how they behave.

Dré shared that her anxiety empowers her sense of intuition, saying:

> "[M]y anxiety, I think, [is] where my intuition comes in and I'm super grateful for my intuition [...] I think your anxiety has a tendency to shape that because it's just a little more in front of my face than it is for other people [...] I'm very slow to question my intuition and I'm grateful for that as well. Even in the face of push back, like I had a conversation yesterday with someone at work that was questioning my opinion about certain things. And I just kind [of] wouldn't let it diminish my opinion in any sort of way because, it's like, 'no,' my in the back of my head, I know I've experienced this situation before. Right now I'm taking action in an appropriate manner and I will [be] steadfast in that. I'm not going to waver. And I kind of have that confidence now. And I think I would feel the same way if I were feeling fully anxious, like maybe having a panic attack or not on my medication, but it would be more of like a frazzled [and] unorganized..."

Similarly, other participants complicated ideas of techno-solutionism by teetering between a device that can solve their problems versus the recognition of her mental health disability as adding value to her life by enabling her to understand herself deeper. For example, concerning her trauma-informed lens, hwho shared:

> "[O]ne thing that's stopping me from going to get neutralized from my trauma is I get a lot of like thrill from dissecting of the wounds myself. So I'm afraid just going to get wires attached to me is going to take away from that experience that I have in the process..."

However, h who also shared that to justify the use of a social robot for her mental health, it needs to *"solve the problem of mental health."* Furthermore, she complicated this by grappling with techno-solutionism to solve how she reacts to external problems:

> "I think having a tool like this [that] helps [...] [and] I can just come to you and all my problems are solved. I think that would be what I want from this device.

You know, that's what I want to think when I think of this tool."

This reflects tensions in the desires of BWA/D where there is understanding of the value of their mental health conditions in shaping their views and approaches to the world. However, at times, participants shared moments that highlighted deep longing for respite from their daily problems, which may motivate techno-solutionist ideas.

7.5 Discussion

This work highlights novel findings for social robot-mediated mental well-being. Although our BWA/D participants had a diverse mental health experiences, there were common themes about how social expectations, due to race, gender, and the confluence of both, exacerbate mental health. In addition, BWA/D face unique experiences when trying to access mental health resources. For example, the lack of diversity of mental health providers means that they may be uncomfortable sharing how social oppression and exclusion, such as racism and sexism, impact their mental health; furthermore, even when they have providers, there are difficulties in receiving support tailored to their specific needs.

The BWA/D participants had diverse perspectives on technology-mediated mental well-being, which informed the varied ways they conceptualized social robot-mediated mental well-being. The participants had diverse ideas about the roles and tasks that social robots could perform to support their mental well-being. Some wanted a social robot to provide functional assistance, limiting its emotional capabilities. In these cases, they wanted to use it simply to keep them on schedule or provide them with information. However, some participants shared ideas about social robots helping them build social and personal awareness; for example, a participant wanted a virtually re-embodied social robot to help them establish and maintain interpersonal boundaries. This demonstrates a spectrum of use cases that range from low socio-emotional function to high socio-emotional functioning within this context. Several participants echoed concerns about using a social robot with high socio-emotional capacities, citing discomfort with robots serving in roles that seem therapeutic. This reflects the awareness of our participants in broader cultural discourses around the socio-emotional risks of social agents of mental health [407].

Still, several participants also considered various socio-emotional tasks a social robot could support, such as providing companionship, listening [402] and helping participants process interpersonal experiences [80]. The findings highlighted socio-ethical considerations for robots in mental health contexts, with participant reflections on the socio-emotional risks of conversational social robots for mental well-being.

Several participants echoed the importance of social robots understanding the realities that Black women experience and providing culturally relevant and culturally tailored responses and recommendations. Moreover, several participants shared the desire for social robots to be conscious of the social realities of Black women, adding an additional understanding of the socio-cognitive skills [56] that social robots should have.

In addition, participants reflected on how the biases in vision and speech models were further ostracizing. Coupled with algorithmic biases in these systems, a robot's appearance can magnify these biases, creating robot microaggressions – a term that extends notions of algorithmic microaggressions [276] to account for physically embodied autonomous systems. Thus, we found that robot behaviors are interpreted differently by people with different social locations; Black women as a marginalized group experienced social robot behaviors. Furthermore, there were findings that extend ideas of inclusivity in HRI, including how metrics, such as trust and safety, especially with mental health contexts, are mediated by social position and vigilance due to lived experiences with navigating healthcare systems [248]. In HRI, there are several concepts that lack understanding of how marginalized people will experience robots. Therefore, notions of epistemic trust [385] are helpful ideas to understand how metrics impact social robot-mediated mental well-being.

7.6 Summary and Recommendations

We conducted a short-term longitudinal, two-phase speculative participatory design approach with Black women with anxiety and/or depression (BWA/D), informed by the pluriversal methodology developed in Chapter 4; furthermore, this work applied the Lived Experience Framework (see Fig. 7.2). We found several socio-culturally responsive roles and tasks that social robots can provide. Moreover, we highlighted the importance of social robots that have robust culturally-responsive socio-cognitive and socio-emotional capabilities. Finally, we contribute socio-technical and socio-ethical considerations for social agents within mental health contexts, especially for marginalized communities.

Social Robot-Mediated Mental Well-being Takeaways

1. Social robots should provide functional assistance. For example, social robots can remind end-users of activities that have direct impact on their mental well-being (e.g., medication and exercise reminders).
2. Enable socio-emotional capabilities with comprehensive guardrails and limitations. For example, a social robot can support some meaning-making through supporting audio journaling.
3. However, social robots that support socio-emotional tasks should be able to recognize signs of severe distress and intentions of harm and direct the end-user to human support (e.g. a hotline).
4. Social robots should have socio-culturally robust socio-cognitive and socio-emotional capabilities, including providing tailored recommendations. Furthermore, socio-emotional responses should highlight awareness of Black women's social realities.
5. Social robots should be available in discreet and portable form factors. For example, re-embodiment of a social robot on a smartwatch as a virtual avatar can support discreetness and portability.
6. There are several ethical risks of conversational social robots in particular, such as triggering negative emotions in users, limitations in detecting and responding to self harm or the harm of others.
7. The HRI evaluation of robots used for health and well-being needs to factor in epistemic trust and how experiences of epistemic injustice and vigilance are shaped by negative social experiences, especially for marginalized communities.

Methodological Takeaways

1. Soma-based practices are self-reflexive processes that helped both the researcher and participants uncover their biases and desires, which is essential for speculations grounded in their lived experiences [134].
2. PD methodologies, including the use of generative kits, scenario-based design (SBD) and (counter)storytelling used in earlier chapters in this thesis, are effective in other HRI contexts, demonstrating their generalizability to other disability populations and robot applications.
3. Soma-based activities were oriented so that the researcher could participate. For example, the researcher engaged in body-scanning with participants, which enabled allowing shared vulnerability and helped disrupt power imbalances in the co-design process [134].

Part V

Service Robot Design Guidelines, Methodological Insights, & Conclusions

8 Discussion

8.1 Summary of Contributions

8.1.1 Design Guidelines & Considerations for Equitable & Inclusive Service Robots

In this section, I summarize the design guidelines, and socio-technical considerations can be drawn from the participatory design studies in this thesis.

1) Communication Modalities

Participants expressed desire for service robots to support various communication/interaction modalities to enhance usability and accessibility. Generally, participants wanted multi-modal input/output (I/O) communication modalities, which included auditory feedback (e.g., speech and non-speech); visual feedback (e.g., lights); or tangible feedback (e.g. haptics).

Furthermore, participants shared that redundancy in interaction modalities available was vital to ensure accessibility across contexts (e.g., private or public) and disability populations. For example, tangible interfaces enabled participants with visual disabilities to access non-visual information through haptic communication (see subsection 3.7.1); however, haptic cues also provided additional sensory feedback to people with mental health disabilities (see subsection 7.4). Furthermore, this created additional interaction opportunities for non-tech users who could leverage on-body buttons. For example, in public settings, participants shared that they desired discreet forms of communication, including haptic cues (e.g., vibration) or on-screen text (see Subsections 3.7.1, 4.4.2, 7.4.5).

Regardless of whether it was a service robot for physical assistance (i.e., item retrieval from delivery robots, see Chapter 4), mobility-related help (i.e., navigation support from a guide robot, see Chapter 3), or emotional/mental support (i.e., social robot, see Chapter 7), participants desired that the interaction with the robot was either direct (e.g., speaking to the robot directly) or mediated by an interface. In the case of an interface, they desired either an on-body (e.g., physical buttons or touch screen on the robot) or off-body (e.g., smartphone application that communicates with the robot) interface.

2) Features, Functions, and Types of Assistance

Across different service contexts, participants have desired varied features that are associated with the specific tasks they need support with. Whether assistive navigation, last-mile delivery, or mental well-being support, participants shared interest in service robots also supporting diverse auxiliary tasks, which depended on the use context and environment. For example, participants wanted assistance with post-delivery tasks, such as identifying and storing items, returning items, commentary on fashion choices. Similarly, participants wanted guide robots to linger after they arrived at their destination and provide additional information, such as the wait time until the bus arrived. Additionally, they also wanted guide robots to foster interdependence; for example, they wanted guide robots to be able to connect them with a person who works in a store, thereby complicating the idea that PwDs only desire independent access. Instead, they want assistance from and connection with other people in their communities, not just with a robot [41]. Lastly, within the context of service robots for mental well-being, participants desired varied types of assistance and tasks. Participants desired utilitarian tasks, such as reminders. Additionally, they also wanted complex assistance with more socio-emotional tasks like companionship, personal reflection, and awareness building. Each of our disabled participants' desired service robot features and functions reflect the richness of how PwDs envision the role of technology in their lives. Moreover, these insights demonstrate that in order to truly support PwDs in their daily lives, service robots must be capable of completing sub-tasks that a PwD may desire support with at the beginning, during, or at the end of the service task.

3) Physical Form Factor and Morphologies

Form factors are the shapes and sizes of the robots and the category. Morphology is how the robot functions mechanically and interacts with the physical world and those within it. Both of these considerations are necessary factors that shape the ways in which service robots can be helpful or harmful to members of the disabled community. In this thesis, we identified several types of form factors and morphologies. These findings suggest PwDs are open to a wide range of ideas about what a robot should look like and how it should interact with the world; this includes wheeled and legged mobile robots, humanoids, drones, and non-anthropomorphic (discreet) social robots. The type of form factor and morphological structure should be context-dependent: disability-related access needs, tasks/sub-tasks, and infrastructure constraints should influence service robot structures. Furthermore, despite preferences for context-dependent form factors and morphologies, participants desired policy to enforce standards (see Chapter3, Sub-section 3.7.1) to increase accessibility.

8.1.2 Socio-technical Considerations

In each service domain, participants highlighted varying ethical and physical risks, including bodily harm, breaches of data privacy, exacerbation of mental health, and increased social exclusion. For example, service robots for autonomous mobility (i.e., guide and delivery robots), which have collision risks, pose physical danger to bystanders of all dis/abilities. Additionally, they can also injure disabled end-users if they do not have the appropriate communication/interaction modalities (see 8.1.1).

In addition, our participants also highlighted ethical risks. For example, participants highlighted how commercial service robots entering private homes was a privacy risk (see 4.4.5). Moreover, participants also highlighted ethical and safety risks due to robotic technologies being non-inclusive. For example, participants sheared how algorithmic bias in multimodal subsystems, such as text-to-speech and vision models (see 7.4.6) could enhance feelings of exclusion. In the mental health context, this could exacerbate marginalized PwDs mental well-being. Moreover, in socio-emotional contexts, providing emotional support can be disrupted by failures to detect the user, misidentifying them as another person, which recreates social harms (e.g., microaggressions) or mispronouncing their name. Nevertheless, in HRI, perceived discrimination from robots and topics related to implications of racialization and gendering of robots are nascent (e.g., [36, 82]). For service robots, which help with tasks in both personal and professional contexts, an end-user's perception of how well those tasks are performed is socially mediated; that is, depending on the social identity of the end-user, their disability status, racial/ethnic, or gender, their perception of a robot's behavior may differ. Although service robots have the potential to help, their potential for harm and further marginalization of already vulnerable communities is critical to consider.

8.1.3 The Lived Experience Framework

Central to the framework presented in this thesis are the following principles, which are salient for inclusive service robots and equitable human-robot interactions.

Principle 1: Leverage Accessible Design Communication.

Shift power towards PwDs by utilizing design communication modalities that are inclusive to diverse adults with disabilities. This would enable them to communicate ideas.

1) Ground ideation in social and technological realities.

Lived experiences are physically embodied. This means that a person's bodily experiences, sensations, perceptions, and memories are important. As such, as part of this thesis, I leveraged first-person perspective methods (see Chapters 3, 4, 7) that enabled participants to leverage their first-hand testimony as both design context and inspiration.

Furthermore, I leveraged theory of mind (ToM) to capture how socio-cognitive processes extend to human-robot processes (see Chapter 6) and uncover how peoples' embodied experiences can (re)shape service robots. Finally, we leveraged a soma-based speculative design processes, which leverage meaning-making towards speculative making concerning technology-mediated mental well-being possibilities (see Chapter 7). Thus, our work shows the importance of grounding service robot ideation in the lived experiences of potential end-users. Their lived experiences can be gleaned from observation (e.g. ToM) or from first-person design methods. Regardless, capturing and centering the lived experiences of PwDs, in particular, is essential for co-creating inclusive and equity-oriented service robots.

2) Use accessible or preferred ideation modalities.

The use of accessible ideation modalities and materials serves an important role in facilitating equitable participation in design ideation [319, 347, 351]. For example, we used verbal scenario-based simulations that leverage reflection-on PwDs' lived experience with navigation (Chapter 3); the use of verbal and written (counter)storytelling (Chapters 4 and 7); and craft materials and tangible materials (e.g. Legos; Chapters 4 and 7).

Design ideation should be facilitated using a range of physical materials [318, 319] and non-physical, such as oral (counter)storytelling [42, 379] that draws on the embodied knowledge of potential end-users [189, 239, 420]. Thus, our work showed how participant reactions to design artifacts can expand beyond physical prototypes to include oral testimony. This thesis demonstrates the value of accessible design modalities as enabling participants to articulate their lived experiences in co-design workshops.

3) Gradually introduce low- to high-technology prototyping materials.

Our efforts towards equitable co-design demonstrated that high-technology prototyping is not vital during early HRI design encounters; in fact, prioritizing high-technology materials can be intimidating at the outset [89, 353]. Instead, we chose to begin encounters with low-technology materials towards low-fidelity prototypes, which proved to be valuable at surfacing novel ideas (e.g. see Chapters 3 and 4). Furthermore, longitudinal co-design studies allowed for the gradual introduction of higher-technology materials and the co-creation of high-fidelity prototypes

4) Promote mutual learning about the design methods used to avoid further marginalization.

Mutual learning is vital and enables people to have more equitable participation [238, 318]. In the process, it is essential to ensure participants gain knowledge about the design methods used and their credibility to avoid feelings of infantilization, especially when low-technology materials and low-fidelity (e.g. craft) approaches are used. Nevertheless, the work in this thesis demonstrates that low-fidelity and low-technology participatory prototyping methods are beneficial for lowering the barrier to participating in the robot co-design process. However, as PwD participants gain competence and confidence in their design skills, employing medium-technology prototyping methods can be valuable. For example, Ostrowski et al. [318] demonstrated the use of block programming as a medium-technology participatory prototyping approach method to enable older adults to have more control over the co-design process. Future work applications of the Lived Experience Framework could employ these strategies.

Principle 2: Confront intersecting Social Marginalizations and Privileges.

Meaningfully engage people with intersecting social marginalizations. Furthermore, it is essential to evoke/facilitate discourse in the process that 1) highlights power relations among participants and researchers and concerning structural factors; and 2) embraces tensions due to differences in lived experiences.

Our work demonstrated that engaging diverse people is central to facilitating discourses about social privileges and marginalizations. In workshops, we aimed to engage disabled participants with intersecting social marginalization; we included the participation of people of color (POCs) with sensory and mobility disabilities; Black women with mental health disabilities; and PwDs from lower socio-economic backgrounds. Differences in social power due to race, gender, class can provide a point of tension [116], not in terms of argument. Instead, these differences create tensions that highlight differences in lived experience. Moreover, design ideation grounded in the lived experiences of potential end-users at the social margins is vital to ensuring inclusive and equitable design outcomes. The nuances of participants' realities, including their material conditions, should be interrogated/engaged during design encounters to avoid issues that can occur during “blue sky” ideation [175]. Still, in the process of engaging diverse cohorts, it is important to avoid tokenization [431] and extractive participation [62]. Instead, it is important to build more lasting community relationships and build sustainable relationships [127]. In this thesis, myself and co-researchers typically did outreach or used existing contact information to recruit participants. Although this work showcases the importance of recruiting and centering work on diverse lived experiences, the relationships developed did not occur at institutional levels across each project. For example, despite some participants being part of several institutional research projects, there was no longstanding communal body where participants could congregate with members of our institution. This is something that needs to be facilitated by both researchers and broader institutions to ensure non-extractive community research with community members, especially those within the disability community.

Moreover, there is value in sharing power though vulnerability in order to disrupt power relations. For example, design processes used in Chapters 4 and 7 were oriented so that participants were less likely to view the researchers as people of authority; instead, they were able to view them as facilitators and collaborators [298]. For example, Chapter 7 included experiences body-scanning with the robot, helping disrupt power imbalances in the co-futuring process [134].

Principle 3: Encourage Reflexivity.

Facilitate activities that evoke introspection about biases, assumptions, desires, in both researchers and participants and embrace alternative design possibilities (e.g., techno-optimism, skepticism, and pessimism/refusal).

Reflexivity is not just an analytical technique [53], but also a way of critically engaging with design ideation. Self-reflexive methods foster reflective engagement with one’s own lived experiences – biases, assumptions, and positionality – and the impact on the research process. For participants, self-reflexive processes are about connecting with their deeper desires through situated and embodied engagements (e.g., diary studies, embodied reflection and articulation). This enables reflection about how and whether technology can help or disrupt their well-being. Furthermore, for HRI design researchers, it is about recognizing our own assumptions about what potential end-users may want and biases towards techno-solutionist ideals and ceding power in favor of community-centered desires.

8.2 Revisiting Thesis Objectives

8.2.1 RQ1: Does situating service robot design in the lived experiences of disabled adults produce inclusive and equitable service robot designs?

Our work foregrounds the lived experiences of diverse PwDs throughout the design process. Throughout these works, I illustrate an inclusive process where there is diverse participation, which is salient for equitable outcomes. Furthermore, our work surfaced several socio-technical considerations (material conditions, social groups, etc). Our work encouraged dialogue and ideation rooted in PwDs lived experiences with systemic inequalities and centered ideation in those experiences. We did not eschew these discourses and they made ideation stronger. Furthermore, the processes even surfaced normally ignored ideas of techno-refusal. That is, the rejection of robots outright (see Chapter 4, subsection 4.4) and the rejection of solutionist ideals (see Chapter 7, subsection 7.4).

Our applications of the Lived Experience Framework generated evidence supporting diverse, inclusive and equity-oriented design guidelines across different types of disabilities and service domains. Furthermore, findings across the several studies that make up this work illustrate the importance of inclusive robot design features, including form factors and morphologies, types of assistance, and multimodal communication. We also found the importance of service robot interfaces having interoperability with existing assistive technologies mobility aids and devices, hearing aids. Additionally, we uncovered that the types of assistance and support PwDs require from service robots is context dependent: assistance depends on a user's disability-related access needs, service-related tasks, and environmental/infrastructure-related factors. Although we have noted that different morphologies and form factors can support PwDs for personal tasks in their living environment, more work needs to be done to understand how this impacts commercial service robots that traverse public spaces before arriving at PwDs' homes (see Chapter 4).

Finally, as we move into a world filled with robots empowered by physical AI, including robot foundation models built on large, multimodal datasets, it is important to consider how these systems may further exclude and harm people with disabilities. In this work, we saw the limitations of multimodal models; for example, biased vision models misdetected Black women (see Chapter 7). Furthermore, emotion recognition models that leverage facial expressions are also inadequate for several disabled population, such as pBLV (see Chapter 3). These subsystems must be made more robust and inclusive to ensure that they are equitable for everyone. Only then will PwDs be able to receive equitable support from service robots.

8.2.2 RQ2: Does centering the lived experience of PwDs make the service robot co-design process more equitable?

In this thesis, we found that methods that center PwDs' lived experiences enabled participants to articulate their ideas. We facilitated mutual learning in various ways to ensure the co-design process was equitable, including presenting a guide robot prototype as a participatory probe (Chapter 3); holding technology demonstrations to provide participants with different possibilities of a delivery robots' morphology (Chapter 4); and creating speculative prototypes to allow participants to gain experiential knowledge of a social robot's capabilities (Chapter 7). Furthermore, short-term longitudinal PD engagements enabled participants situate service robot design iteration in their evolving lived experiences; this allowed them to re-shape technology based on their own experiences, resulting in rich and specific service robot design guidelines.

In contrast to other equity-oriented PD frameworks in HRI [316] where stakeholders who were not part of end-user populations (e.g., design practitioners, graduate students, faculty) embraced the refusal of autonomous systems, our work enabled discourse around techno-skepticism and anti-solutionism with end-user populations. This typically manifested as participants being able to refuse certain service robot ideas, such as refusing delivery robots in favor of humans (Chapter 4). This emerged for several reasons. First, some members of the disability community are already activists and advocates due to their lived experiences rallying against structural inequities. Therefore, they may be comfortable calling out technology that can do harm to their communities. Second, members of marginalized populations experience epistemic injustice (i.e., silencing of their knowledge) and when presented the opportunity to critique technologies that may be pernicious, they may feel comfortable doing so. Finally, which needs to be explored further, I believe the identities of researchers and their social positions may have been salient for fostering safe spaces for these discourses. For example, the rapport built and constant reminders of refusal during co-design of delivery robots demonstrated the researchers' comfort with critiques of robots. In other work in this thesis, shared identities enabled a researcher and participants to feel more comfortable discussing shared social oppressions (see Chapter 7). Finally, ethical disclosures about mental health disability enable participants to gain understanding of shared experience.

We recognize that these conditions may not be replicable by all researchers. Still, our work demonstrates that fostering respectful relationality between researchers and participants is conducive to research settings in which participants can rally against potentially harmful technological outcomes [298]. Similarly, we showed how shared vulnerability by researcher participating self-reflexive processes alongside participants disrupts of power differentials [49]. Finally, we also noted that failures to consider how unmet access needs in mixed disability groups can disrupt equitable participation of group members in the design process and exacerbate exclusion (see Chapter 4). To mitigate these factors, it is essential to ensure access needs are collected and to engage participants in iterative feedback about the quality of workshops on the basis of accessibility.

8.3 Limitations & Future Work

The main limitations of this thesis are: 1) user evaluations and high-fidelity robot deployments; 2) mutual learning participatory system prototyping with participants; and 3) focus on service robot design within the Global North context.

First, the focus of this thesis is to ensure people with disabilities can equitably participate the service robot co-design process and uncover design recommendations for inclusive and equity-oriented human-robot interactions within these use contexts. As such, I focused on facilitating generative activities and iterative evaluations centered on PwD participants' lived experiences towards novel service robot specifications. In the process, I leveraged both low- to high-technology materials to co-create varied fidelity prototypes. Furthermore, I did not perform controlled studies to evaluate the usability of specific service robot prototypes nor the usability engendered by the design specifications gleaned each participatory design study. Future work can focus on evaluation of service robot prototypes with PwDs. Moreover, in HRI, there are calls for longitudinal robot deployments as part of the user evaluation process (e.g. [178, 318]). Therefore, future work could explore whether the service robot design guidelines result in seamless and inclusive user interactions.

In this thesis, I highlighted the importance of mutual learning in the co-design process, especially when focusing on complex systems like robots. As such, we gradually introduced low- to high-technology materials across Chapters 4 and 7, demonstrating a process that de-centers physical prototyping at the outset in favor of more accessible ideation materials. However, previous work has demonstrated the value of low-barrier systems prototyping as a mutual learning that enables participants to have more control over the design process [318]. For example, Ostrowski et al. [318] used block programming as a low-barrier participatory approach to enable older adults to prototype social robot interactions. Future work could employ these strategies

Finally, despite the Lived Experience Framework drawing from critical and decolonial methodologies, this work was performed exclusively in the context of the Global North. In future work, it would be valuable to assess whether and how our methodological framework would expand, contract, or break down if applied in the Global South, especially considering the disparate access to autonomous technologies. Furthermore, it is important to capture how different social landscapes, including social/disability policies and infrastructure constraints, can re-shape the principles that comprise the Framework. Additionally, in the Global South, there have been longstanding decolonial movements. Currently, scholars focused on decolonial theory have applied these notions to autonomous systems, such as artificial intelligence (AI). Thus, Decolonial AI [289] challenges the design and implementation of autonomous technologies and how their current forms reinforce colonial oppression [289]. Therefore, applications of the Framework in the Global South would have to confront how and whether service robots as autonomous systems reify colonial ways-of-knowing via algorithmic oppression as well as the implications on social structures (e.g. labor). In the process, the Framework should not only capture the social and political realities of PwDs and other marginalized communities, but also post-colonial and decolonial initiatives that affect all people within the Global South. Therefore, future implementations of the Lived Experience Framework should also seek to understand how “inclusivity” and “equity” are defined in communities across the Global South — not just local societies, but also in relation to Western hegemony.

8.4 Conclusion

In this thesis, I present the Lived Experience Framework as a methodological approach to designing inclusive and equitable service robots with disabled adults. I demonstrate the application of this framework across three domains, assistive navigation, last-mile delivery, and mental well-being. It also shares specific service robot design guidelines revealed during implementation of the Framework, illustrating the value of this approach. Furthermore, our methodological framework showcased how rooting design in the lived experiences of people at the social margins uncovers specific design guidelines and socio-technical considerations for inclusive service robots and equitable human-robot experiences. Finally, this thesis highlights the importance of embracing the experience-as-expertise of people with disabilities who are not robot design practitioners; it showcases that by democratizing the co-design of robots, a enabling yet disruptive technology, can yield meaningful contributions.

BIBLIOGRAPHY

[1] 2024. URL https://www.unesco.org/en/query-list/i/inclusive. 1.4.3

[2] 2024. URL https://www.unesco.org/en/query-list/s/social-equity. 1.4.3

[3] 2025. URL https://www.psychiatry.org/patients-families/neurodevelopment-disorders. 1.4

[4] 2026. URL https://adaparc.shinyapps.io/ADA_PARC/#section-city-data. 1.4.4

[5] 99PI. Curb cuts - 99 URL https://99percentinvisible.org/episode/308-curb-cuts/. 1.1

[6] Annemarie Abbing, Anne Ponstein, Susan van Hooren, Leo de Sonneville, Hanna Swaab, and Erik Baars. The effectiveness of art therapy for anxiety in adults: A systematic review of randomised and non-randomised controlled trials. *PloS one*, 13 (12):e0208716, 2018. 5.3.1

[7] Rotem Abraham, Noemi Grinspun, and Tal-Chen Rabinowitch. Children's perception of interpersonal coordination during joint painting. *Scientific Reports*, 12(1):18897, 2022. 6.1, 6.2.1, 6.2.2, 6.2.3, 6.5.1, 6.5.3

[8] Rotem Abraham, Noemi Grinspun, and Tal-Chen Rabinowitch. Painting in coordination is perceived as a positive interpersonal interaction. *The Arts in Psychotherapy*, 83:102020, 2023. 6.1, 6.2.1, 6.2.2, 6.2.3, 6.3.2, 6.3.3, 6.5.1, 6.5.3

[9] Emily Ackerman. Lessons From My Standoff With an Autonomous Sidewalk Robot — bloomberg.com. https://www.bloomberg.com/news/articles/2019-11-19/why-tech-needs-more-designers-with-disabilities, 2019. 1.1, 4.1

[10] Muhammad Sadi Adamu and Makuochi Samuel Nkwo. \" remembering" as a decolonial praxis in african hci and design. In *Proceedings of the 4th African Human*

Computer Interaction Conference, pages 118–124, 2023. 4.2.2

[11] Sarah Aldaweesh, Ghzal Alelsheikh, Falwah Alhamed, Max Van Kleek, and Nigel Shadbolt. "it hasn't lived in our society": Investigating cultural sensitivity in llm chatbots for emotional support. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems*, pages 1–20, 2026. 7.2.1

[12] Sven Alfonsson, Karin Johansson, Jonas Uddling, and Timo Hursti. Differences in motivation and adherence to a prescribed assignment after face-to-face and online psychoeducation: an experimental study. *BMC psychology*, 5(1):3, 2017. 5.3.2

[13] Mustafa Ali. Towards a decolonial computing. 2014. 4.2.2, 7.2.3

[14] Syed Mustafa Ali. A brief introduction to decolonial computing. *XRDS: Crossroads, The ACM Magazine for Students*, 22(4):16–21, 2016. 4.2.2, 7.2.3

[15] Teresa Almeida, Rob Comber, and Madeline Balaam. Hci and intimate care as an agenda for change in women's health. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 2599–2611, 2016. 7.2.3

[16] Adriana Alvarado Garcia, Juan F Maestre, Manuhuia Barcham, Marilyn Iriarte, Marisol Wong-Villacres, Oscar A Lemus, Palak Dudani, Pedro Reynolds-Cuéllar, Ruotong Wang, and Teresa Cerratto Pargman. Decolonial pathways: Our manifesto for a decolonizing agenda in hci research and design. In *Extended abstracts of the 2021 CHI conference on human factors in computing systems*, pages 1–9, 2021. 4.2.2

[17] Laura Helena Andrade, Jordi Alonso, Zeina Mneimneh, JE Wells, Ali Al-Hamzawi, Guilherme Borges, Evelyn Bromet, Ronny Bruffaerts, G De Girolamo, R De Graaf, et al. Barriers to mental health treatment: results from the who world mental health surveys. *Psychological medicine*, 44(6):1303–1317, 2014. 5.3.2

[18] Georgios Angelopoulos, Alessandra Rossi, Claudia Di Napoli, and Silvia Rossi. You are in my way: non-verbal social cues for legible robot navigation behaviors. In *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 657–662. IEEE, 2022. 4.2.1

[19] Ian A Apperly and Stephen A Butterfill. Do humans have two systems to track beliefs and belief-like states? *Psychological review*, 116(4):953, 2009. 2.1.4

[20] Jacopo M Araujo, Guangtao Zhang, John Paulin Paulin Hansen, and Sadasivan Puthusserypady. Exploring eye-gaze wheelchair control. In *ACM symposium on eye tracking research and applications*, pages 1–8, 2020. 4.5.1

[21] Emilie Maria Nybo Arendttorp, Kasper Rodil, Heike Winschiers-Theophilus, and Christof Magoath. Overcoming legacy bias: Re-designing gesture interactions in virtual reality with a san community in namibia. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–18, 2022. 4.2.2

[22] Victoria Gray Armstrong, Egle Dalinkeviciute, and Josephine Ross. A dyadic art psychotherapy group for parents and infants–piloting quantitative methodologies for evaluation. *International Journal of Art Therapy*, 24(3):113–124, 2019. 6.2.1, 6.5.1

[23] Arthur Aron, Elaine N Aron, Michael Tudor, and Greg Nelson. Close relationships as including other in the self. *Journal of personality and social psychology*, 60(2): 241, 1991. 6.3.3

[24] Arthur Aron, Elaine N Aron, and Danny Smollan. Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of personality and social psychology*, 63(4):596, 1992. 6.3.3

[25] American Psychological Association, 2023. URL https://www.apa.org/practice/digital-therapeutics-mobile-health. 5.3.2

[26] The American Speech-Language-Hearing Association. Augmentative and Alternative Communication (AAC) — asha.org. https://www.asha.org/public/speech/disorders/aac/?srsltid=AfmBOooB1h-DzxFttxCHK8Urmq9x-tqW3Io9TNjl9EzdPBI1a55GNjDm. 4.4.2, 4.5.1

[27] Selma Auala, Heike Winschiers-Theophilus, and Naska Goagoses. Co-designing learning supports for cultural virtual reality experiences with namibian primary school learners. In *Proceedings of the 24th Interaction Design and Children*, pages 961–966. 2025. 4.2.2

[28] Minja Axelsson, Raquel Oliveira, Mattia Racca, and Ville Kyrki. Social robot co-design canvases: A participatory design framework. *ACM Transactions on Human-Robot Interaction (THRI)*, 11(1):1–39, 2021. 1.2

[29] Shiri Azenkot, Catherine Feng, and Maya Cakmak. Enabling building service robots to guide blind people: A participatory design approach. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 3–10, 2016. doi: 10.1109/HRI.2016.7451727. 1.2, 3.1, 3.2.1, 3.7.1, 3.8, 3.8.1, 3.8.2

[30] Zinzi D Bailey, Nancy Krieger, Madina Agénor, Jasmine Graves, Natalia Linos, and Mary T Bassett. Structural racism and health inequities in the usa: evidence and interventions. *The lancet*, 389(10077):1453–1463, 2017. 7.1

[31] Shaheja S Bandealy, Nima C Sheth, Samantha K Matuella, Jeremy R Chaikind, Isabelle A Oliva, Samantha R Philip, Paul M Jones, and Elizabeth A Hoge. Mind-body interventions for anxiety disorders: a review of the evidence base for mental health practitioners. *Focus*, 19(2):173–183, 2021. 7.3.3

[32] Liam Bannon, Jeffrey Bardzell, and Susanne Bødker. Introduction: Reimagining participatory design—emerging voices, 2018. 1.2, 2.2.2

[33] Jeffrey Bardzell and Shaowen Bardzell. What is" critical" about critical design? In *Proceedings of the SIGCHI conference on human factors in computing systems*,

pages 3297–3306, 2013. 2.2.3

[34] Colin Barnes and Geof Mercer. Disability: key concepts. *Polity*, 2003. 1.4.1

[35] Christoph Bartneck, Dana Kulić, Elizabeth Croft, and Susana Zoghbi. Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International journal of social robotics*, 1:71–81, 2009. 3.2.3

[36] Christoph Bartneck, Kumar Yogeeswaran, Qi Min Ser, Graeme Woodward, Robert Sparrow, Siheng Wang, and Friederike Eyssel. Robots and racism. In *Proceedings of the 2018 ACM/IEEE international conference on human-robot interaction*, pages 196–204, 2018. 7.4.6, 8.1.2

[37] Ruha Benjamin. Race after technology. In *Social Theory Re-Wired*, pages 405–415. Routledge, 2023. 7.4.6

[38] Cynthia Bennett, Emily Ackerman, Bonnie Fan, Jeffrey Bigham, Patrick Carrington, and Sarah Fox. Accessibility and the crowded sidewalk: Micromobility's impact on public space. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference*, pages 365–380, 2021. 1.2, 4.1, 4.2.1, 4.4.3, 4.4.7, 7.3.3

[39] Cynthia L Bennett. *Toward centering access in professional design*. PhD thesis, 2020. 1.1

[40] Cynthia L Bennett and Daniela K Rosner. The promise of empathy: Design, disability, and knowing the" other". In *Proceedings of the 2019 CHI conference on human factors in computing systems*, pages 1–13, 2019. 1.2, 1.4.3, 2.1.3

[41] Cynthia L Bennett, Erin Brady, and Stacy M Branham. Interdependence as a frame for assistive technology research and design. In *Proceedings of the 20th international acm sigaccess conference on computers and accessibility*, pages 161–173, 2018. 8.1.1

[42] Cynthia L Bennett, Burren Peil, and Daniela K Rosner. Biographical prototypes: Reimagining recognition and disability in design. In *Proceedings of the 2019 on Designing Interactive Systems Conference*, pages 35–47, 2019. 4.3.2, 4.4.7, 8.1.3

[43] Cynthia L Bennett, Cole Gleason, Morgan Klaus Scheuerman, Jeffrey P Bigham, Anhong Guo, and Alexandra To. "it's complicated": Negotiating accessibility and (mis) representation in image descriptions of race, gender, and disability. In *Proceedings of the 2021 chi conference on human factors in computing systems*, pages 1–19, 2021. 1.2, 3.8.4, 4.2.2

[44] Frank J Bernieri. Coordinated movement and rapport in teacher-student interactions. *Journal of Nonverbal behavior*, 12(2):120–138, 1988. 6.1, 6.2.1, 6.5.1, 6.5.3

[45] Frank J Bernieri and Robert Rosenthal. Interpersonal coordination: Behavior matching and interactional synchrony.(1991). *Studies in emotion & social interaction.*

Fundamentals of Nonverbal Behavior, pages 401–432, 1991. 6.1, 6.2.1

[46] Alberto Betella and Paul FMJ Verschure. The affective slider: A digital self-assessment scale for the measurement of human emotions. *PloS one*, 11(2):e0148037, 2016. 7.3.3

[47] Abena Boadi-Agyemang and Minjung Park. Designing interactive agents to support emotion regulation in the workplace through guided art-making. In *Companion of the 2024 ACM/IEEE International Conference on Human-Robot Interaction*, pages 257–262, 2024. 5, 6.1, 6.2.3

[48] Abena Boadi-Agyemang, Peter Schaldenbrand, Vihaan Misra, Elizabeth J Carter, Jean Oh, and Aaron Steinfeld. If i move, do you move? investigating the role of interpersonal synchrony in human-robot joint painting. In *2025 34th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pages 728–735. IEEE, 2025. 6

[49] Abena Boadi-Agyemang, Adinawa D Adjagbodjou, and Jay L Cunningham. Relational and somatic engagements with anxious and depressed black women: A speculative design approach to social robot-mediated mental well-being. In *Proceedings of the 2026 Conference on Creativity and Cognition*, pages 1343–1349, 2026. 7, 7.3.3, 8.2.2

[50] Abena Boadi-Agyemang, Sanika Moharana, Cynthia L Bennett, Elizabeth J Carter, Patrick Carrington, and Aaron Steinfeld. Pluriversal approach to co-designing delivery robots with people with disabilities. In *Proceedings of the 21st ACM/IEEE International Conference on Human-Robot Interaction*, pages 285–294, 2026. 4, 7.3.2

[51] Susanne Bødker, Christian Dindler, Ole S Iversen, and Rachel C Smith. What is participatory design? In *Participatory design*, pages 5–13. Springer, 2022. 1.2, 2.1.2, 2.2.2, 3.4, 7.2.1

[52] Soo Borson, Anna Korpak, Pedro Carbajal-Madrid, Denise Likar, Gretchen A Brown, and Romilla Batra. Reducing barriers to mental health care: Bringing evidence-based psychotherapy home. *Journal of the American Geriatrics Society*, 67(10): 2174–2179, 2019. 5.2

[53] Virginia Braun, Victoria Clarke, Nikki Hayfield, Louise Davey, and Elizabeth Jenkinson. Doing reflexive thematic analysis. In *Supporting research in counselling and psychotherapy: Qualitative, quantitative, and mixed methods research*, pages 19–38. Springer, 2023. 8.1.3

[54] Kirsten Bray and Christina Harrington. Speculative blackness: Considering afrofuturism in the creation of inclusive speculative design probes. In *Proceedings of the 2021 ACM designing interactive systems conference*, pages 1793–1806, 2021. 7.1, 7.2.3, 7.3.3, 7.3.3

[55] Cynthia Breazeal. Regulation and entrainment in human—robot interaction. *The International Journal of Robotics Research*, 21(10-11):883–902, 2002. 1, 2

[56] Cynthia Breazeal, Kerstin Dautenhahn, and Takayuki Kanda. Social robotics. *Springer handbook of robotics*, pages 1935–1972, 2016. 5.3.2, 5.5, 7.1, 7.5

[57] Cynthia L Breazeal, Anastasia K Ostrowski, Nikhita Singh, and Hae Won Park. Designing social robots for older adults. *Natl. Acad. Eng. Bridge*, 49:22–31, 2019. 5.3.2

[58] TEB Breen. I think therefore i am.... *An exploration of artificial intelligence (AI) marketing practitioner perceptions and practices, Universitat Ramon Llull. FCRIB-Humanitats i Ciències Socials. Preuzeto*, 13:2020, 2020. 5.3.3

[59] Joshua Breslau, Kenneth S Kendler, Maxwell Su, Sergio Gaxiola-Aguilar, and Ronald C Kessler. Lifetime risk and persistence of psychiatric disorders across ethnic groups in the united states. *Psychological medicine*, 35(3):317–327, 2005. 7.1

[60] Christina Bröhl, Jochen Nelles, Christopher Brandl, Alexander Mertens, and Verena Nitsch. Human–robot collaboration acceptance model: Development and comparison for Germany, Japan, China and the USA. *International Journal of Social Robotics*, 11(5):709–726, 2019. 6.3.3

[61] Debra L Brucker, Sophie Mitra, Navena Chaitoo, and Joseph Mauro. More likely to be poor whatever the measure: Working-age persons with disabilities in the united states. *Social Science Quarterly*, 96(1):273–296, 2015. 4.1, 4.2.2, 4.5

[62] Finn Brunton and Helen Nissenbaum. *Obfuscation: A user's guide for privacy and protest*. Mit Press, 2015. 8.1.3

[63] Elizabeth Taylor Buck, Kim Dent-Brown, Glenys Parry, and Jonathan Boote. Dyadic art psychotherapy: Key principles, practices and competences. *The Arts in Psychotherapy*, 41(2):163–173, 2014. 5.4

[64] US Census Bureau. About the topic of race, Jan 2018. URL `https://www.census.gov/topics/population/race/about.html`. 7.3.1

[65] Madeline Burghardt. The human bottom of non-human things: On critical theory and its contributions to critical disability studies. *Critical Disability Discourses*, 2011. 2.2.2

[66] Lindsey A Burke, Sandra Chijioke, and Thomas P Le. Gendered racial microaggressions and emerging adult black women's social and general anxiety: Distress intolerance and stress as mediators. *Journal of Clinical Psychology*, 79(4):1051–1069, 2023. 7.1

[67] Emily A Butler and Ashley K Randall. Emotional coregulation in close relationships. *Emotion Review*, 5(2):202–210, 2013. 5.4

[68] Barbara A Butrica, Stipica Mudrazija, and Jonathan Schwabish. *Geography of*

Disability and Food Insecurity. Urban Institute Washington, DC, 2022. 4.2.2, 4.5

[69] Susanne Bφdker, Kaj Grφnbæk, and Morten Kyng. Cooperative design: techniques and experiences from the scandinavian scene. In *Readings in human–computer interaction*, pages 215–224. Elsevier, 1995. 1.2, 2.2.2, 7.2.1

[70] Stephanie Cacioppo, Haotian Zhou, George Monteleone, Elizabeth A Majka, Kimberly A Quinn, Aaron B Ball, Gregory J Norman, Gün R Semin, and John T Cacioppo. You are in sync with me: neural correlates of interpersonal synchrony with a partner. *Neuroscience*, 277:842–858, 2014. 6.1

[71] Rafael A. Calvo and Sidney D'Mello. Affect detection: An interdisciplinary review of models, methods, and their applications. *IEEE Transactions on Affective Computing*, 1(1):18–37, 2010. doi: 10.1109/T-AFFC.2010.1. 3.8.3

[72] Christine H Carrington. Clinical depression in african american women: Diagnoses, treatment, and research. *Journal of clinical psychology*, 62(7):779–791, 2006. 5.1

[73] John M Carrol. Five reasons for scenario-based design. In *Proceedings of the 32nd annual hawaii international conference on systems sciences. 1999. hicss-32. abstracts and cd-rom of full papers*, pages 11–pp. IEEE, 1999. 2.1.3, 3

[74] John M Carroll. Scenario-based design. In *Handbook of human-computer interaction*, pages 383–406. Elsevier, 1997. 1.2, 2.1.3, 4.3.2

[75] Manuela Celi, Valentina Rognoli, and Camilo Ayala-Garcia. Prototypes for speculative design research. In *The Role of Prototypes in Design Research: Overview and Case Studies*, pages 61–84. Springer, 2023. 7.3.3

[76] Prabha S Chandra. Embodied distress in reproductive psychiatry. *World Psychiatry*, 24(2):222, 2025. 5.1

[77] Rachel Charlotte Smith, Heike Winschiers-Theophilus, Asnath Paula Kambunga, and Sarala Krishnamurthy. Decolonizing participatory design: Memory making in namibia. In *Proceedings of the 16th Participatory Design Conference 2020-Participation (s) Otherwise-Volume 1*, pages 96–106, 2020. 1.6, 2.2.3, 7.2.3

[78] James I Charlton. *Nothing about us without us: Disability oppression and empowerment*. Univ of California Press, 1998. 1.4.1

[79] Rhitu Chatterjee. Their teenage sons died by suicide. now, they are sounding an alarm about ai chatbots. *NPR, September*, 19, 2025. 7.2.1, 7.4.4

[80] Aaron Chatterji, Thomas Cunningham, David J Deming, Zoe Hitzig, Christopher Ong, Carl Yan Shan, and Kevin Wadman. How people use chatgpt. Technical report, National Bureau of Economic Research, 2025. 7.4.4, 7.5

[81] Mathew Chiang, William Bernard Reid-Varley, and Xiaoduo Fan. Creative art therapy for mental illness. *Psychiatry research*, 275:129–136, 2019. 5.3.1

[82] Meia Chita-Tegmark, Monika Lohani, and Matthias Scheutz. Gender effects in

perceptions of robots and humans with varying emotional intelligence. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 230–238. IEEE, 2019. 8.1.2

[83] Meia Chita-Tegmark, Theresa Law, Nicholas Rabb, and Matthias Scheutz. Can you trust your trust measure? In *Proceedings of the 2021 ACM/IEEE international conference on human-robot interaction*, pages 92–100, 2021. 6.3.3

[84] Mina Choi, Rachel Kornfield, Leila Takayama, and Bilge Mutlu. Movement matters: effects of motion and mimicry on perception of similarity and closeness in robot-mediated communication. In *Proceedings of the 2017 CHI conference on human factors in computing systems*, pages 325–335, 2017. 6.1, 6.2.3, 6.5.1

[85] Tina Chou, Anu Asnaani, and Stefan G Hofmann. Perception of racial discrimination and psychopathology across three us ethnic minority groups. *Cultural diversity & ethnic minority psychology*, 18(1):74, 2012. 5.4, 7.2.2

[86] Tzu-Kuan Chuang, Ni-Ching Lin, Jih-Shi Chen, Chen-Hao Hung, Yi-Wei Huang, Chunchih Teng, Haikun Huang, Lap-Fai Yu, Laura Giarré, and Hsueh-Cheng Wang. Deep trail-following robotic guide dog in pedestrian environments for people who are blind and visually impaired - learning from virtual and real worlds. In *2018 IEEE International Conference on Robotics and Automation (ICRA)*, pages 5849–5855, 2018. doi: 10.1109/ICRA.2018.8460994. 3.1

[87] Rodney Clark, Norman B Anderson, Vernessa R Clark, and David R Williams. Racism as a stressor for african americans: A biopsychosocial model. *American psychologist*, 54(10):805, 1999. 5.4, 7.2.2

[88] Victoria Clarke and Virginia Braun. *Successful Qualitative Research: A Practical Guide for Beginners*. Sage Publications, Ltd., 2013. 3.6

[89] John Clarkson. Countering design exclusion–theory and practice. In *Design for Inclusivity*, pages 165–180. Routledge, 2016. 1.1, 8.1.3

[90] Patricia Hill Collins. *Black feminist thought: Knowledge, consciousness, and the politics of empowerment*. routledge, 2022. 3.8.4

[91] Centers For Disease Control and Prevention. Disability and health overview, Dec 2024. URL https://www.cdc.gov/disability-and-health/about/index.html. 1.4.4

[92] Martin Cooney. Robot art, in the eye of the beholder?: Personalized metaphors facilitate communication of emotions and creativity. *Frontiers in Robotics and AI*, 8: 668986, 2021. 5.3.3, 6.1, 6.2.3

[93] Flora Cornish, Nancy Breton, Ulises Moreno-Tabarez, Jenna Delgado, Mohi Rua, Ama de Graft Aikins, and Darrin Hodgetts. Participatory action research. *Nature Reviews Methods Primers*, 3(1):34, 2023. 2.2.2

[94] Sasha Costanza-Chock. *Design justice: Community-led practices to build the worlds we need*. MIT press, 2020. 1.6

[95] Joana Coutinho, Alfredo Pereira, Patrícia Oliveira-Silva, Deborah Meier, Vladimiro Lourenço, and Wolfgang Tschacher. When our hearts beat together: Cardiac synchrony as an entry point to understand dyadic co-regulation in couples. *Psychophysiology*, 58(3):e13739, 2021. 5.4

[96] Sha'Mira DeAnne Covington. *The Revolution Will Be Embodied: An Archival Meditation on the Corporeal Narratives of Black Femmes and the Somatics of Joy and Pleasure (1930s to 1980s)*. PhD thesis, University of Georgia, 2023. 7.2.3

[97] Kimberlé Williams Crenshaw. Mapping the margins: Intersectionality, identity politics, and violence against women of color. In *The public nature of private violence*, pages 93–118. Routledge, 2013. 1.2, 3.8.4

[98] Jay Cunningham, Gabrielle Benabdallah, Daniela Rosner, and Alex Taylor. On the grounds of solutionism: Ontologies of blackness and hci. *ACM Transactions on Computer-Human Interaction*, 30(2):1–17, 2023. 7.2.3, 7.4.6

[99] Michelle Dalencour, Eunice C Wong, Lingqi Tang, Elizabeth Dixon, Aziza Lucas-Wright, Kenneth Wells, and Jeanne Miranda. The role of faith-based organizations in the depression care of african americans and hispanics in los angeles. *Psychiatric Services*, 68(4):368–374, 2017. 1.4.4

[100] Lily Dallow. "It cut me off:" WeHo man with cerebral palsy raises concerns after delivery robot incident. KTLA, Sep 2025. URL https://ktla.com/news/local-news/weho-man-with-cerebral-palsy-raises-concerns-after-delivery-robot-collision/. 1.1, 4.1

[101] Nana-Ama Danquah. *Willow weep for me: A Black woman's journey through depression*. WW Norton & Company, 2023. 7.3.3

[102] Elizabeth B daSilva and Adrienne Wood. How and why people synchronize: An integrated perspective. *Personality and Social Psychology Review*, page 10888683241252036, 2024. 6.1, 6.2.2

[103] Kerstin Dautenhahn, Alan Bond, Lola Canamero, and Bruce Edmonds. Socially intelligent agents: Creating relationships with computers and robots. In *Socially Intelligent Agents: Creating Relationships with Computers and Robots*, pages 1–20. Springer, 2002. 5.3.2

[104] Mark H Davis. Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of personality and social psychology*, 44(1): 113, 1983. 6.3.1

[105] MH Davis. A multidimensional approach to individual differences in empathy. *JSAS*

Catalog of Selected Documents in Psychology, 1980. 6.3.1

[106] Claudia Berlim de Mello, Thiago da Silva Gusmão Cardoso, and Marcus Vinicius C Alves. Social cognition development and socioaffective dysfunction in childhood and adolescence. *Social and affective neuroscience of everyday human interaction: From theory to methodology*, pages 161–175, 2022. 1.6, 7.4.5

[107] Sabina Deitrick, Scott Beach, Ellen Kinnee, Janet Schlarb, Christianne Accurso, and Chris Briem. Allegheny county quality of life survey 2023 -results by race prepared by allegheny county quality of life survey 2023 results by race, 2020. URL https://ucsurlib.pitt.edu/files/center/2023. 1.4.4

[108] Emilie Delaherche, Mohamed Chetouani, Ammar Mahdhaoui, Catherine Saint-Georges, Sylvie Viaux, and David Cohen. Interpersonal synchrony: A survey of evaluation methods across disciplines. *IEEE Transactions on Affective Computing*, 3 (3):349–365, 2012. 6.2.1

[109] Nathaniel Dennler, Changxiao Ruan, Jessica Hadiwijoyo, Brenna Chen, Stefanos Nikolaidis, and Maja Matarić. Design metaphors for understanding user expectations of socially interactive robot embodiments. *ACM Transactions on Human-Robot Interaction*, 12(2):1–41, 2023. 7.3.3

[110] Sunita R Deshmukh, John Holmes, and Alastair Cardno. Art therapy for people with dementia. *Cochrane Database of Systematic Reviews*, (9), 2018. 5.3.1

[111] Universal Design. The principles of universal design. *Recuperado de www. design. ncsu. edu/cud*, 3, 1997. 2.2.1

[112] Audrey Desjardins, Oscar Tomico, Andrés Lucero, Marta E Cecchinato, and Carman Neustaedter. Introduction to the special issue on first-person methods in hci, 2021. 2.1.3, 7.2.3

[113] Caroline K Diehl, Wendy Heller, Cindy M Yee, and Gregory A Miller. Theories of psychopathology: Potential to promote clinical science, empowerment, and justice. *Journal of psychopathology and clinical science*, 132(3):330, 2023. 5.2, 7.2.2

[114] Tawanna R Dillahunt, Sylvia Simioni, and Xuecong Xu. Online grocery delivery services: an opportunity to address food disparities in transportation-scarce areas. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–15, 2019. 4.1, 4.2.1, 4.4.1, 4.5

[115] Carl DiSalvo, Andrew Clement, and Volkmar Pipek. Participatory design for, with, and by communities. *International handbook of participatory design*, pages 182–209, 2012. 1.2, 2.2.2

[116] Lynn Dombrowski, Ellie Harmon, and Sarah Fox. Social justice-oriented interaction design: Outlining key design strategies and commitments. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, pages 656–671, 2016. 2,

3, 1.6, 2.2.3, 8.1.3

[117] Paul Dourish. *Where the action is: the foundations of embodied interaction*. MIT press, 2001. 2.1.3

[118] Rob Drew. Technological determinism. *A companion to popular culture*, pages 165–183, 2016. 1

[119] Sahana D'Silva, Cristina Poscablo, Racheline Habousha, Mikhail Kogan, and Benjamin Kligler. Mind-body medicine therapies for a range of depression severity: a systematic review. *Psychosomatics*, 53(5):407–423, 2012. 5.3.1

[120] Elisabeth Dubois, Xiaojun Yuan, DeeDee Bennett Gayle, Pallavi Khurana, Thora Knight, Salimah Laforce, David Turetsky, and David Wild. Socially vulnerable populations adoption of technology to address lifestyle changes amid covid-19 in the us. *Data and Information Management*, 6(2):100001, 2022. 1.1

[121] Brian R Duffy, Gregory MP O'Hare, Alan N Martin, John F Bradley, and Bianca Schon. Agent chameleons: Agent minds and bodies. In *Proceedings 11th IEEE International Workshop on Program Comprehension*, pages 118–125. IEEE, 2003. 5.3.2

[122] Anthony Dunne and Fiona Raby. *Speculative Everything, With a new preface by the authors: Design, Fiction, and Social Dreaming*. MIT press, 2024. 2.2.3, 7.2.3, 7.3.3

[123] Lisa Egede, Leslie Coney, Brittany Johnson, Christina Harrington, and Denae Ford. " for us by us": Intentionally designing technology for lived black experiences. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference*, pages 3210–3224, 2024. 7.2.1, 7.2.3

[124] Nabil Eid. Innovation and technology for persons with disabilities. *KN4DC project, UN-ESCWA, Chairman of Studies Center for Handicapped Research and Consultant in ICT for inclusion and development PwDs*, 2015. 1.1

[125] Sarah A Elwood and Deborah G Martin. "placing" interviews: Location and scales of power in qualitative research. *The professional geographer*, 52(4):649–657, 2000. 4.3.2

[126] Sheena Erete, Aarti Israni, and Tawanna Dillahunt. An intersectional approach to designing in the margins. *interactions*, 25(3):66–69, 2018. 2, 3

[127] Sheena Erete, Eric Corbett, Natasha Smith-Walker, Jay L Cunningham, Erin Gatz, Tina Park, Tam Perry, Lauren Wilcox, and Remi Denton. Towards equitable community-industry collaborations: Understanding the experiences of nonprofits' collaborations with tech companies. *Proceedings of the ACM on Human-Computer Interaction*, 9(2):1–31, 2025. 8.1.3

[128] Arturo Escobar. Sustainability: Design for the pluriverse. *Development*, 54(2): 137–140, 2011. 4.1

[129] Arturo Escobar. *Designs for the pluriverse: Radical interdependence, autonomy, and the making of worlds*. Duke University Press, 2018. 4.1

[130] Alison Faulkner. Survivor research and mad studies: the role and value of experiential knowledge in mental health research. *Disability & Society*, 32(4):500–520, 2017. 5.1

[131] David Feil-Seifer and Maja J Matarić. Socially assistive robotics. *IEEE robotics & automation magazine*, 18(1):24–31, 2011. 5.3.2, 7.1

[132] Jennifer Fereday and Eimear Muir-Cochrane. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International journal of qualitative methods*, 5(1):80–92, 2006. 4.3.3

[133] Emilio Ferrer and Jonathan L Helm. Dynamical systems modeling of physiological coregulation in dyadic interactions. *International journal of psychophysiology*, 88 (3):296–308, 2013. 5.4

[134] Aisha K Finch. Black feminism and the practice of care. *Palimpsest*, 11(1):1–208, 2022. 7.2.3, 1, 3, 8.1.3

[135] Terrence Fong, Illah Nourbakhsh, and Kerstin Dautenhahn. A survey of socially interactive robots. *Robotics and autonomous systems*, 42(3-4):143–166, 2003. 5.3.2

[136] National Center for Complementary and Integrative Health. Complementary, alternative, or integrative health: what's in a name? *NCCIH*, 2021. 5.3.1

[137] Centers for Disease Control and Prevention (CDC). Infographic: Adults with disabilities: Ethnicity and race, Dec 2024. URL https://www.cdc.gov/disability-and-health/articles-documents/infographic-adults-with-disabilities-ethnicity-and-race.html. 1.4.4

[138] Disability Inclusion & Access Moving Forward. URL https://disabilityinclusionpgh.org/disability-statistics/. 1.4.4

[139] Poetry Foundation. The robots are coming by kyle dargan, Nov 2022. URL https://www.poetryfoundation.org/poems/58202/the-robots-are-coming. 1.1

[140] Thomas Franke, Christiane Attig, and Daniel Wessel. A personal resource for technology interaction: development and validation of the affinity for technology interaction (ATI) scale. *International Journal of Human–Computer Interaction*, 35 (6):456–467, 2019. 6.3.1

[141] Christopher Frauenberger, Judith Good, and Wendy Keay-Bright. Phenomenology, a framework for participatory design. In *Proceedings of the 11th biennial participatory design conference*, pages 187–190, 2010. 1.2

[142] Martin Calisto Friant, Paola Velasco-Herrejón, and Thomas Bauwens. Pluriver-

sal technologies: Innovation inspired by indigenous worldviews. *E-international Relations*, 2023. 1.2, 4.1

[143] Luis A Fuente, Hannah Ierardi, Michael Pilling, and Nigel T Crook. Influence of upper body pose mirroring in human-robot interaction. In *International Conference on Social Robotics*, pages 214–223. Springer, 2015. 5.3.3

[144] Ken Fujiwara and Ikuo Daibo. Empathic accuracy and interpersonal coordination: behavior matching can enhance accuracy but interactional synchrony may not. *The Journal of Social Psychology*, 162(1):71–88, 2022. 6.1

[145] Mafalda Gamboa. Robots are increasingly: Imagination crisis in human-computer interaction research. In *Proceedings of the sixth decennial Aarhus conference: Computing X Crisis*, pages 216–222, 2025. 1

[146] Paula M Gardiner, Kelly D McCue, Lily M Negash, Teresa Cheng, Laura F White, Leanne Yinusa-Nyahkoon, Brian W Jack, and Timothy W Bickmore. Engaging women with an embodied conversational agent to deliver mindfulness and lifestyle recommendations: A feasibility randomized control trial. *Patient education and counseling*, 100(9):1720–1729, 2017. 7.2.1

[147] Tami Gavron. Meeting on common ground: Assessing parent–child relationships through the joint painting procedure. *Art Therapy*, 30(1):12–19, 2013. 6.2.1

[148] Tami Gavron. The joint painting procedure: Parents and children creating shared space. *Art Therapy Online*, 8(1), 2017. 6.2.1

[149] Tami Gavron and Ofra Mayseless. Creating art together as a transformative process in parent-child relations: The therapeutic aspects of the joint painting procedure. *Frontiers in psychology*, 9:2154, 2018. 6.2.1

[150] Robert Geirhos, Patricia Rubisch, Claudio Michaelis, Matthias Bethge, Felix A Wichmann, and Wieland Brendel. Imagenet-trained cnns are biased towards texture; increasing shape bias improves accuracy and robustness. In *International conference on learning representations*, 2018. 6.5.1

[151] Samuel Gerald Collins. Working for the robocracy: Critical ethnography of robot futures. *Anthropology of Work Review*, 39(1):5–9, 2018. 1

[152] Moojan Ghafurian, Shruti Chandra, Rebecca Hutchinson, Angelica Lim, Ishan Baliyan, Jimin Rhim, Garima Gupta, Alexander M Aroyo, Samira Rasouli, and Kerstin Dautenhahn. Systematic review of social robots for health and wellbeing: a personal healthcare journey lens. *ACM Transactions on Human-Robot Interaction*, 14(1):1–48, 2025. 5.3.2, 5.3.3, 5.3.4, 7.1, 7.2.1

[153] Howard Giles and Peter Powesland. Accommodation theory. *Sociolinguistics: A reader*, pages 232–239, 1997. 6.1

[154] Nikki Giovanni. *Cotton Candy on a Rainy Day*. ProQuest LLC, 2004. 7.3.3

[155] Haben Girma. The robots occupying our sidewalks | TechCrunch — techcrunch.com. https://techcrunch.com/2020/08/11/the-robots-occupying-our-sidewalks/, 2020. 1.1, 4.1

[156] Dan Goodley, Rebecca Lawthom, Kirsty Liddiard, and Katherine Runswick-Cole. Provocations for critical disability studies. *Disability & Society*, 34(6):972–997, 2019. 2.1.2

[157] John D Gould and Clayton Lewis. Designing for usability: key principles and what designers think. *Communications of the ACM*, 28(3):300–311, 1985. 2.2.2

[158] Connor Graham and Mark Rouncefield. Probes and participation. In *Proceedings of the Tenth Anniversary Conference on Participatory Design 2008*, pages 194–197, 2008. 2.2.3, 7.3.3

[159] Tyler Greenawalt. Amazon's drones deliver items in 60 minutes or less—here's how we simplified the process — aboutamazon.com. https://www.aboutamazon.com/news/transportation/amazon-drone-deliver-package, 2025. 4.2.1

[160] James J Gross. The emerging field of emotion regulation: An integrative review. *Review of general psychology*, 2(3):271–299, 1998. 5.3.1

[161] James J Gross and Oliver P John. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of personality and social psychology*, 85(2):348, 2003. 5.3.1

[162] Bern Grush. How robots and humans can safely share public spaces, Sep 2025. URL https://www.weforum.org/stories/2025/09/how-robots-humans-can-share-public-spaces/. 1.1, 1.5

[163] Lisa Guenther. Six senses of critique for critical phenomenology. *Puncta*, 4(2):5–23, 2021. 2.1.2

[164] João Guerreiro, Dragan Ahmetovic, Daisuke Sato, Kris Kitani, and Chieko Asakawa. Airport accessibility and navigation assistance for people with visual impairments. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, page 1–14, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450359702. doi: 10.1145/3290605.3300246. URL https://doi.org/10.1145/3290605.3300246. 3.7.1

[165] João Guerreiro, Daisuke Sato, Saki Asakawa, Huixu Dong, Kris M. Kitani, and Chieko Asakawa. Cabot: Designing and evaluating an autonomous navigation robot for blind people. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS '19, page 68–82, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450366762. doi: 10.1145/3308561.3353771. 3.1, 3.7.1

[166] João Guerreiro, Daisuke Sato, Saki Asakawa, Huixu Dong, Kris M. Kitani, and Chieko Asakawa. Cabot: Designing and evaluating an autonomous navigation robot for blind people. In *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS '19, page 68–82, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450366762. doi: 10.1145/3308561.3353771. URL https://doi.org/10.1145/3308561.3353771. 3.7.1

[167] Carlos Guerrero Millan, Bettina Nissen, and Larissa Pschetz. Cosmovision of data: An indigenous approach to technologies for self-determination. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, pages 1–13, 2024. 1.2, 4.1

[168] David Gussak. The effectiveness of art therapy in reducing depression in prison populations. *International Journal of Offender therapy and comparative Criminology*, 51(4):444–460, 2007. 5.3.1

[169] Judith A Hall, Jinni A Harrigan, and Robert Rosenthal. Nonverbal behavior in clinician—patient interaction. *Applied and preventive psychology*, 4(1):21–37, 1995. 6.2.1

[170] Kaveh Akbari Hamed, Vinay R. Kamidi, Wen-Loong Ma, Alexander Leonessa, and Aaron D. Ames. Hierarchical and safe motion control for cooperative locomotion of robotic guide dogs and humans: A hybrid systems approach. *IEEE Robotics and Automation Letters*, 5(1):56–63, 2020. doi: 10.1109/LRA.2019.2939719. 3.1

[171] Howard Han, Franklin Mingzhe Li, Nikolas Martelaro, Daragh Byrne, and Sarah E Fox. The robot in our path: Investigating the perceptions of people with motor disabilities on navigating public space alongside sidewalk robots. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*, pages 1–6, 2023. 4.1, 4.2.1, 4.3.3, 4.4.2, 4.5.1

[172] Howard Ziyu Han, Franklin Mingzhe Li, Alesandra Baca Vazquez, Daragh Byrne, Nikolas Martelaro, and Sarah E Fox. Co-design accessible public robots: Insights from people with mobility disability, robotic practitioners and their collaborations. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, pages 1–20, 2024. 1.2, 4.1, 4.2.1, 4.3.3, 4.4.2, 4.4.3, 4.5.1, 4.5.2

[173] Thomas Hanna. What is somatics. *Somatics: Magazine-journal of the bodily arts and sciences*, 5(4):4–8, 1986. 7.2.3

[174] Christina Harrington and Tawanna R Dillahunt. Eliciting tech futures among black young adults: A case study of remote speculative co-design. In *Proceedings of the 2021 CHI conference on human factors in computing systems*, pages 1–15, 2021. 7.2.3, 7.3.3

[175] Christina Harrington, Sheena Erete, and Anne Marie Piper. Deconstructing

community-based collaborative design: Towards more equitable participatory design engagements. *Proceedings of the ACM on human-computer interaction*, 3(CSCW): 1–25, 2019. 1.2, 2.2.2, 4.2.2, 4.5.2, 8.1.3

[176] Christina N Harrington, Aashaka Desai, Aaleyah Lewis, Sanika Moharana, Anne Spencer Ross, and Jennifer Mankoff. Working at the intersection of race, disability and accessibility. In *proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*, pages 1–18, 2023. 4.2.2

[177] Amanda W Harrist and Ralph M Waugh. Dyadic synchrony: Its structure and function in children's development. *Developmental review*, 22(4):555–592, 2002. 6.2.1

[178] Justin Hart, Elliot Hauser, Samuel Baker, Joydeep Biswas, Junfeng Jiao, and Luis Sentis. Longitudinal social impacts of hri over long-term deployments. In *2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 1258–1260. IEEE, 2022. 8.3

[179] Syed Khursheed Hasnain, Ghiles Mostafaoui, Robin Salesse, Ludovic Marin, and Philippe Gaussier. Intuitive human robot interaction based on unintentional synchrony: A psycho-experimental study. In *2013 IEEE Third Joint International Conference on Development and Learning and Epigenetic Robotics (ICDL)*, pages 1–7. IEEE, 2013. 6.1

[180] Ryosuke Hasumoto, Kazuhiro Nakadai, and Michita Imai. Reactive chameleon: a method to mimic conversation partner's body sway for a robot. *International Journal of Social Robotics*, 12(1):239–258, 2020. 6.2.3

[181] Marion A. Hersh and Michael A. Johnson. A robotic guide for blind people. part 1. a multi-national survey of the attitudes, requirements and preferences of potential end-users. *Applied Bionics and Biomechanics*, 7(4):277–288, 2010. doi: 10.1080/11762322.2010.523626. URL https://doi.org/10.1080/11762322.2010.523626. 3.2.1, 3.8.1

[182] Kana Higashino, Mitsuhiko Kimoto, Takamasa Iio, Katsunori Shimohara, and Masahiro Shiomi. Is politeness better than impoliteness? comparisons of robot's encouragement effects toward performance, moods, and propagation. *International Journal of Social Robotics*, 15(5):717–729, 2023. 4.4.3

[183] Clareese Hill. Speculative black feminist epistemologies of worldbuilding for xr. *Frontiers in Communication*, 9:1371081, 2024. 7.2.3

[184] Jesse Hoey, Krists Zutis, Valerie Leuty, and Alex Mihailidis. A tool to promote prolonged engagement in art therapy: design and development from arts therapist requirements. In *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility*, pages 211–218, 2010. 5.3.3, 6.1, 6.2.3

[185] Megan Hofmann, Devva Kasnitz, Jennifer Mankoff, and Cynthia L Bennett. Living

disability theory: Reflections on access, research, and design. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility*, pages 1–13, 2020. 2.1.3

[186] Stefan G Hofmann, Alice T Sawyer, Angela Fang, and Anu Asnaani. Emotion dysregulation model of mood and anxiety disorders. *Depression and anxiety*, 29(5): 409–416, 2012. 5.3.1

[187] Karen Holtzblatt and Hugh Beyer. *Contextual Design: Defining Customer-centered Systems*. Elsevier, 1997. 3.6

[188] Kristina Hook. *Designing with the body: Somaesthetic interaction design*. MIt Press, 2018. 2.1.3, 7.2.3, 7.3.3, 7.3.3, 1, 7.3.4

[189] Kristina Höök, Sara Eriksson, Marie Louise Juul Søndergaard, Marianela Ciolfi Felice, Nadia Campo Woytuk, Ozgun Kilic Afsar, Vasiliki Tsaknaki, and Anna Ståhl. Soma design and politics of the body. In *Proceedings of the Halfway to the Future Symposium 2019*, pages 1–8, 2019. 8.1.3

[190] Bell Hooks et al. Marginality as a site of resistance. *Out there: Marginalization and contemporary cultures*, 4:341–343, 1990. 1.1, 2

[191] Mokter Hossain. Autonomous delivery robots: A literature review. *IEEE Engineering Management Review*, 51(4):77–89, 2023. 4.1, 4.2.1

[192] Noura Howell, Audrey Desjardins, and Sarah Fox. Cracks in the success narrative: Rethinking failure in design research through a retrospective trioethnography. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 28(6):1–31, 2021. 2.1.3, 2.2.2

[193] Yinying Hu, Xiaojun Cheng, Yafeng Pan, and Yi Hu. The intrapersonal and interpersonal consequences of interpersonal synchrony. *Acta Psychologica*, 224:103513, 2022. 6.2.1

[194] Val Huet. Literature review of art therapy-based interventions for work-related stress. *International Journal of Art Therapy*, 20(2):66–76, 2015. 5.3.1

[195] Edmund Husserl. *Introduction to the logical investigations: A draft of a preface to the logical investigations (1913)*. Springer Science & Business Media, 2012. 2.1.1

[196] Mosi Adesina Ifatunji, Yanica Faustin, Wendy Lee, and Deshira Wallace. Black nativity and health disparities: a research paradigm for understanding the social determinants of health. *International Journal of Environmental Research and Public Health*, 19(15):9166, 2022. 7.2.2, 7.3.1

[197] Sonia Ingoglia, Alida Lo Coco, and Paolo Albiero. Development of a brief form of the Interpersonal Reactivity Index (B–IRI). *Journal of Personality Assessment*, 98 (5):461–471, 2016. 6.3.1

[198] Tariq Iqbal, Samantha Rack, and Laurel D Riek. Movement coordination in human–

robot teams: a dynamical systems approach. *IEEE Transactions on Robotics*, 32(4): 909–919, 2016. 5.3.3, 6.1, 6.2.3

[199] Lilly Irani, Janet Vertesi, Paul Dourish, Kavita Philip, and Rebecca E Grinter. Post-colonial computing: a lens on design and development. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 1311–1320, 2010. 2.2.3

[200] Carla S Jakobowsky, Anna MH Abrams, and Astrid M Rosenthal-von der Pütten. Gaze-cues of humans and robots on pedestrian ways. *International Journal of Social Robotics*, 16(2):311–325, 2024. 4.2.1

[201] Watthanasak Jeamwatthanachai, Mike Wald, and Gary Wills. Indoor navigation by blind people: Behaviors and challenges in unfamiliar spaces and buildings. *British Journal of Visual Impairment*, 37(2):140–153, 2019. doi: 10.1177/0264619619833723. URL https://doi.org/10.1177/0264619619833723. 3.2.1

[202] Candace C Johnson, Karen M Sheffield, and Roy E Brown. Mind-body therapies for african-american women at risk for cardiometabolic disease: A systematic review. *Evidence-Based Complementary and Alternative Medicine*, 2018(1):5123217, 2018. 5.3.1, 7.3.3

[203] Audrey L Jones, Susan D Cochran, Jane Rafferty, Robert Joseph Taylor, and Vickie M Mays. Lifetime and twelve-month prevalence, persistence, and unmet treatment needs of mood, anxiety, and substance use disorders in african american and us versus foreign-born caribbean women. *International journal of environmental research and public health*, 17(19):7007, 2020. 7.2.2

[204] June Jordan. *Haruko/Love poems*. Serpent's Tail, 2023. 7.3.3

[205] Girija Kaimal, Katrina Carroll-Haskins, Marygrace Berberian, Abby Dougherty, Natalie Carlton, and Arun Ramakrishnan. Virtual reality in art therapy: a pilot qualitative study of the novel medium and implications for practice. *Art Therapy*, 37 (1):16–24, 2020. 5.3.3

[206] Asnath Paula Kambunga, Rachel Charlotte Smith, Heike Winschiers-Theophilus, and Ton Otto. Decolonial design practices: Creating safe spaces for plural voices on contested pasts, presents, and futures. *Design Studies*, 86:101170, 2023. 2.2.3, 4.2.2

[207] Nandini Karunamuni, Ikuyo Imayama, and Dharshini Goonetilleke. Pathways to well-being: Untangling the causal relationships among biopsychosocial variables. *Social science & medicine*, 272:112846, 2021. 1.2

[208] Seita Kayukawa, Keita Higuchi, João Guerreiro, Shigeo Morishima, Yoichi Sato, Kris Kitani, and Chieko Asakawa. Bbeep: A sonic collision avoidance system for blind travellers and nearby pedestrians. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–12, 2019. 3.7.1

[209] Seita Kayukawa, Daisuke Sato, Masayuki Murata, Tatsuya Ishihara, Akihiro Kosugi, Hironobu Takagi, Shigeo Morishima, and Chieko Asakawa. How users, facility managers, and bystanders perceive and accept a navigation robot for visually impaired people in public buildings. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pages 546–553, 2022. doi: 10.1109/RO-MAN53752.2022.9900717. 3.7.1

[210] Finn Kensing and Jeanette Blomberg. Participatory design: Issues and concerns. *Computer supported cooperative work (CSCW)*, 7(3):167–185, 1998. 2.2.2

[211] kff. Kff/cnn mental health in america survey, Oct 2022. URL https://www.kff.org/mental-health/kff-cnn-mental-health-in-america-survey/. 5.2

[212] Abby C King, Timothy W Bickmore, Maria Ines Campero, Leslie A Pruitt, and James Langxuan Yin. Employing virtual advisors in preventive care for underserved communities: results from the compass study. *Journal of health communication*, 18 (12):1449–1464, 2013. 7.2.1

[213] Brian Kinnee, Audrey Desjardins, and Daniela Rosner. Autospeculation: Reflecting on the intimate and imaginative capacities of data analysis. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–10, 2023. 7.2.3, 7.3.3

[214] Kheng Lee Koay, Michael L Walters, and Kerstin Dautenhahn. Methodological issues using a comfort level device in human-robot interactions. In *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005.*, pages 359–364. IEEE, 2005. 3.2.3

[215] Svenja Koehne, Mirjam J Schmidt, and Isabel Dziobek. The role of interpersonal movement synchronisation in empathic functions: Insights from tango argentino and capoeira. *International Journal of Psychology*, 51(4):318–322, 2016. 6.1

[216] Sander L Koole and Wolfgang Tschacher. Synchrony in psychotherapy: A review and an integrative framework for the therapeutic alliance. *Frontiers in psychology*, 7: 862, 2016. 5.3.1, 6.1, 6.2.1

[217] Sander L Koole, Dana Atzil-Slonim, Emily Butler, Suzanne Dikker, Wolfgang Tschacher, and Tom Wilderjans. In sync with your shrink: Grounding psychotherapy in interpersonal synchrony. In *Applications of social psychology*, pages 161–184. Routledge, 2020. 5.4, 1

[218] Mateja Kovacic, Simon Marvin, and Aidan While. Regulating sidewalk delivery robots as a disruptive new urban technology. *Urban Geography*, 45(7):1236–1255, 2024. 4.4.7

[219] Ellen E Kozelka, Stephanie C Acquilano, Monirah Al-Abdulmunem, Sue Guarino, Glyn Elwyn, Robert E Drake, and Elizabeth Carpenter-Song. Documenting the

digital divide: Identifying barriers to digital mental health access among people with serious mental illness in community settings. *SSM-Mental Health*, 4:100241, 2023. 5.2

[220] Hideki Kozima, Marek P Michalowski, and Cocoro Nakagawa. Keepon: A playful robot for research, therapy, and entertainment. *International Journal of social robotics*, 1:3–18, 2009. 5.3.3, 6.1, 6.2.3

[221] Susanna Krämer, Eyal Ginosar, Marion Koelle, Heiko Müller, Susanne Boll, and Jessica Cauchard. "i have a package for mr. and mrs. smith, can you point me to their house?"—co-designing bystanders' interaction with autonomous delivery vehicles. *ACM Transactions on Human-Robot Interaction*, 14(3):1–29, 2025. 4.2.1

[222] Kurt Kroenke and Robert L Spitzer. The phq-9: a new depression diagnostic and severity measure, 2002. 7.3.1

[223] Candace R Kuby and Rebecca C Christ. An ethico-onto-epistemological pedagogy of qualitative research: Knowing/being/doing in the neoliberal academy. *Socially just pedagogies: Posthumanist, feminist and materialist perspectives in higher education*, pages 131–147, 2018. 1.2

[224] Dana Kulic and Elizabeth Croft. Anxiety detection during human-robot interaction. In *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 616–621. IEEE, 2005. 2.1.4, 3.2.3

[225] Dana Kulić and Elizabeth Croft. Physiological and subjective responses to articulated robot motion. *Robotica*, 25(1):13–27, 2007. 2.1.4, 3.2.3

[226] Dana Kulic and Elizabeth A Croft. Affective state estimation for human–robot interaction. *IEEE transactions on robotics*, 23(5):991–1000, 2007. 2.1.4, 3.2.3

[227] Vladimir A. Kulyukin and Chaitanya Gharpure. Ergonomics-for-one in a robotic shopping cart for the blind. In *Proceedings of the 1st ACM SIGCHI/SIGART Conference on Human-Robot Interaction*, HRI '06, page 142–149, New York, NY, USA, 2006. Association for Computing Machinery. ISBN 1595932941. doi: 10.1145/1121241.1121267. URL https://doi.org/10.1145/1121241.1121267. 3.7.1, 3.8

[228] Masaki Kuribayashi, Seita Kayukawa, Hironobu Takagi, Chieko Asakawa, and Shigeo Morishima. Linechaser: A smartphone-based navigation system for blind people to stand in lines. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450380966. doi: 10.1145/3411764.3445451. URL https://doi.org/10.1145/3411764.3445451. 3.7.1, 3.8

[229] Masaki Kuribayashi, Tatsuya Ishihara, Daisuke Sato, Jayakorn Vongkulbhisal, Karnik Ram, Seita Kayukawa, Hironobu Takagi, Shigeo Morishima, and Chieko Asakawa. Pathfinder: Designing a map-less navigation system for blind people

in unfamiliar buildings. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, New York, NY, USA, 2023. Association for Computing Machinery. ISBN 9781450394215. doi: 10.1145/3544548.3580687. URL https://doi.org/10.1145/3544548.3580687. 3.1, 3.2.2, 3.7.1, 3.8, 3.8.2

[230] E Kuru, Y Safak, İ Özdemir, RG Tulacı, K Özdel, NG Özkula, and S Örsel. Cognitive distortions in patients with social anxiety disorder: Comparison of a clinical group and healthy controls. *The European Journal of Psychiatry*, 32(2):97–104, 2018. 7.4.1

[231] Maria KE Lahman, Rowen Thomas, and Eric D Teman. A good name: Pseudonyms in research. *Qualitative Inquiry*, 29(6):678–685, 2023. 4.3.2

[232] Daniël Lakens. Movement synchrony and perceived entitativity. *Journal of Experimental Social Psychology*, 46(5):701–708, 2010. 6.1, 6.2.1

[233] Daniël Lakens and Mariëlle Stel. If they move in sync, they must feel in sync: Movement synchrony leads to attributions of rapport and entitativity. *Social Cognition*, 29 (1):1–14, 2011. 6.1, 6.2.1, 6.5.1, 6.5.3, 6.6

[234] Jessica L Lakin, Valerie E Jefferis, Clara Michelle Cheng, and Tanya L Chartrand. The chameleon effect as social glue: Evidence for the evolutionary significance of nonconscious mimicry. *Journal of nonverbal behavior*, 27:145–162, 2003. 6.1

[235] Christelle Langley, Bogdan Ionut Cirstea, Fabio Cuzzolin, and Barbara J Sahakian. Theory of mind and preference learning at the interface of cognitive science, neuroscience, and ai: A review. *Frontiers in artificial intelligence*, 5:778852, 2022. 2.1.4

[236] Shaimaa Lazem, Danilo Giglitto, Makuochi Samuel Nkwo, Hafeni Mthoko, Jessica Upani, and Anicia Peters. Challenges and paradoxes in decolonising hci: A critical discussion. *Computer Supported Cooperative Work (CSCW)*, 31(2):159–196, 2022. 4.2.2

[237] Hee Rin Lee and Selma Šabanović. Weiser's dream in the korean home: collaborative study of domestic roles, relationships, and ideal technologies. In *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*, pages 637–646, 2013. 2.1.4, 2.2.2, 1

[238] Hee Rin Lee, Selma Šabanović, Wan-Ling Chang, Shinichi Nagata, Jennifer Piatt, Casey Bennett, and David Hakken. Steps toward participatory design of social robots: mutual learning with older adults with depression. In *Proceedings of the 2017 ACM/IEEE international conference on human-robot interaction*, pages 244–253, 2017. 1.2, 2.1.4, 2.2.2, 8.1.3

[239] Wonjun Lee, Youn-kyung Lim, and Richard Shusterman. Practicing somaesthetics: exploring its impact on interactive product design ideation. In *Proceedings of the*

2014 conference on Designing interactive systems, pages 1055–1064, 2014. 2.1.3, 4.3.2, 7.2.3, 7.3.3, 7.3.3, 7.3.4, 8.1.3

[240] Hagen Lehmann, Joan Saez-Pons, Dag Sverre Syrdal, and Kerstin Dautenhahn. In good company? Perception of movement synchrony of a non-anthropomorphic robot. *PloS one*, 10(5):e0127747, 2015. 6.3.3

[241] Paul M Lehrer and Richard Gevirtz. Heart rate variability biofeedback: how and why does it work? *Frontiers in psychology*, 5:756, 2014. 5.4

[242] Wentao Lei, Mingming Fan, and Juliann Thang. "i shake the package to check if it's mine" a study of package fetching practices and challenges of blind and low vision people in china. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–15, 2022. 4.4.1

[243] Renata M Leitão. Pluriversal worlding: Design, narratives, and metaphors for societal transformation. *AM Časopis za studije umetnosti i medija*, (30):17–35, 2023. 4.2.2

[244] Iolanda Leite, André Pereira, Samuel Mascarenhas, Carlos Martinho, Rui Prada, and Ana Paiva. The influence of empathy in human–robot relations. *International journal of human-computer studies*, 71(3):250–260, 2013. 6.5.1

[245] Emma Marie Lethbridge and Mr. Chris Muldoon. Development of a mobility-related quality-of-life measure for individuals with vision impairments. *Journal of Visual Impairment & Blindness*, 112(2):169–181, 2018. doi: 10.1177/0145482X1811200205. URL `https://doi.org/10.1177/0145482X1811200205`. 3.3

[246] Kaylyn Levine. "the bus is accessible, but how do you get to the bus": First and last mile experiences of disabled transit riders. *Journal of Public Transportation*, 26: 100086, 2024. 4.1, 4.2.1

[247] Chun Li, Jaemarie Solyst, Safiyyah Scott, Gabriella Howse, Tara Nkrumah, Erin Walker, Amy Ogan, and Angela EB Stewart. " i am a technology creator": Black girls as technosocial change agents in a culturally-responsive robotics camp. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*, pages 1–14, 2025. 7.1

[248] Elizabeth Li, Chloe Campbell, Nick Midgley, and Patrick Luyten. Epistemic trust: a comprehensive review of empirical insights and implications for developmental psychopathology. *Research in Psychotherapy: Psychopathology, Process, and Outcome*, 26(3):704, 2023. 7.4.6, 7.5

[249] Jamy Li. The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *International Journal of Human-Computer Studies*, 77:23–37, 2015. 5.3.2

[250] Yinmiao Li, Jennifer Nwogu, Amanda Buddemeyer, Jaemarie Solyst, Jina Lee,

Erin Walker, Amy Ogan, and Angela EB Stewart. “i want to be unique from other robots”: Positioning girls as co-creators of social robots in culturally-responsive computing education. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–14, 2023. 7.1

[251] Jirachaya "Fern" Limprayoon, Prithu Pareek, Xiang Zhi Tan, and Aaron Steinfeld. Robot trajectories when approaching a user with a visual impairment. In *Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS ’21, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450383066. doi: 10.1145/3441852.3476538. URL https://doi.org/10.1145/3441852.3476538. 3.7.1, 3.8

[252] Jessica Lindblom, Beatrice Alenljung, and Erik Billing. Evaluating the user experience of human–robot interaction. *Human-robot interaction: evaluation methods and their standardization*, pages 231–256, 2020. 6.3.3

[253] Pamela Lindgren and Sara Ljungblad. Drones as accessibility probes in able-bodied norms: Insights from people with lived experiences of disabilities. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference*, pages 2946–2957, 2024. 4.5.1

[254] Sandra Littletree, Miranda Belarde-Lewis, and Marisa Duarte. Centering relationality: A conceptual model to advance indigenous knowledge organization practices. 2020. 7.2.3

[255] Roberto Lloréns, Enrique Noé, Carolina Colomer, and Mariano Alcañiz. Effectiveness, usability, and cost-benefit of a virtual reality–based telerehabilitation program for balance recovery after stroke: A randomized controlled trial. *Archives of physical medicine and rehabilitation*, 96(3):418–425, 2015. 5.3.2

[256] Audre Lorde. *Audre Lorde: The Black Unicorn*. University of Missouri, 1979. 7.3.3

[257] Audre Lorde. *The cancer journals*. Penguin, 2020. 7.3.3

[258] Tamara Lorenz, Astrid Weiss, and Sandra Hirche. Synchrony and reciprocity: Key mechanisms for social companion robots in therapy and care. *International Journal of Social Robotics*, 8(1):125–143, 2016. 6.1

[259] Rachael Luck. What is it that makes participation in design participatory design? *Design studies*, 59:1–8, 2018. 2.1.3

[260] Michal Luria, Samantha Reig, Xiang Zhi Tan, Aaron Steinfeld, Jodi Forlizzi, and John Zimmerman. Re-embodiment and co-embodiment: Exploration of social presence for robots and conversational agents. In *Proceedings of the 2019 on Designing Interactive Systems Conference*, pages 633–644, 2019. 5.3.2

[261] Ron Mace. What is universal design. *The Center for Universal Design at North Carolina State University*, 19:2004, 1997. 2.2.1

[262] Paul MacInnes. Toyota pauses paralympics self-driving buses after one hits visually impaired athlete, Aug 2021. URL https://www.theguardian.com/technology/2021/aug/28/toyota-pauses-paralympics-self-driving-buses-after-one-hits-visually-impaired-athlete. 1.1

[263] Dominik Mahr, Gaby Odekerken-Schröder, and Mark Steins. Service robots and innovation: An ecosystem approach. *Journal of Product Innovation Management*, 42(5):874–896, 2025. 1.4.2

[264] Cathy A Malchiodi. *Expressive therapies*. Guilford Publications, 2013. 5.3.1

[265] Bertram F Malle and Daniel Ullman. A multidimensional conception and measure of human-robot trust. In *Trust in human-robot interaction*, pages 3–25. Elsevier, 2021. 4.4.7, 7.4.6

[266] Jennifer Mankoff, Gillian R Hayes, and Devva Kasnitz. Disability studies as a source of critical inquiry for the field of assistive technology. In *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility*, pages 3–10, 2010. 1.4.1

[267] Ana Teresa Martins, Luís Faísca, Helena Vieira, and Gabriela Gonçalves. Emotional recognition and empathy both in deaf and blind adults. *The Journal of Deaf Studies and Deaf Education*, 24(2):119–127, 2019. 3.8.3

[268] Maja J Matarić and Brian Scassellati. Socially assistive robotics. *Springer handbook of robotics*, pages 1973–1994, 2016. 1.4.2, 5.3.2, 7.1

[269] Kayla Matheus, Marynel Vázquez, and Brian Scassellati. A social robot for anxiety reduction via deep breathing. In *2022 31st IEEE international conference on robot and human interactive communication (RO-MAN)*, pages 89–94. IEEE, 2022. 1, 2

[270] Kayla Matheus, Marynel Vázquez, and Brian Scassellati. Ommie: The design and development of a social robot for anxiety reduction. *ACM Transactions on Human-Robot Interaction*, 14(2):1–34, 2025. 5.3.3

[271] Oluwaseun Matiluko. Decolonising the master's house: how black feminist epistemologies can be and are used in decolonial strategy. In *Decolonisation and the Law School*, pages 79–93. Routledge, 2024. 7.2.3

[272] Terika McCall, Muhammad Osama Ali, Fei Yu, Paul Fontelo, and Saif Khairat. Development of a mobile app to support self-management of anxiety and depression in african american women: usability study. *JMIR formative research*, 5(8):e24393, 2021. 5.3.4, 7.1

[273] Terika McCall, Megan Threats, Malvika Pillai, Adnan Lakdawala, and Clinton S Bolton III. Recommendations for design of a mobile application to support management of anxiety and depression among black american women. *Frontiers in Digital*

Health, 4:1028408, 2022. 5.3.4, 7.1

[274] Terika McCall, Meagan Foster, and Todd A Schwartz. Attitudes toward seeking mental health services and mobile technology to support the management of depression among black american women: cross-sectional survey study. *Journal of medical Internet research*, 25:e45766, 2023. 5.3.4, 7.1

[275] Irma McClaurin. *Black feminist anthropology: Theory, politics, praxis, and poetics*. Rutgers University Press, 2025. 7.1, 7.2.3, 7.3.3

[276] Emma McClure and Benjamin Wald. Algorithmic microaggressions. *Feminist Philosophy Quarterly*, 8(3/4), 2022. 7.5

[277] David H McFarland. Respiratory markers of conversational interaction. *Journal of speech, language, and hearing research*, 44(1):128–143, 2001. 5.4

[278] Lucy M McGarry and Frank A Russo. Mirroring in dance/movement therapy: Potential mechanisms behind empathy enhancement. *The Arts in Psychotherapy*, 38 (3):178–184, 2011. 6.1

[279] Melinda A Mende and Hendrikje Schmidt. Psychotherapy in the framework of embodied cognition—does interpersonal synchrony influence therapy success? *Frontiers in Psychiatry*, 12:562490, 2021. 6.1

[280] Maurice Merleu-Ponty. Phenomenology of perception. *Trans. Colin Smith. New York: Humanities Press, and London: Routledge & Kegan Paul*, 1962. 2.1.1

[281] Oussama Metatla, Nick Bryan-Kinns, Tony Stockman, and Fiore Martin. Designing with and for people living with visual impairments: audio-tactile mock-ups, audio diaries and participatory prototyping. *CoDesign*, 11(1):35–48, 2015. 4.1, 4.3.2, 4.3.2

[282] Oussama Metatla, Alison Oldfield, Taimur Ahmed, Antonis Vafeas, and Sunny Miglani. Voice user interfaces in schools: Co-designing for inclusion with visually-impaired and sighted pupils. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–15, 2019. 3.2.2

[283] Marek P Michalowski, Selma Sabanovic, and Hideki Kozima. A dancing robot for rhythmic social interaction. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, pages 89–96, 2007. 6.1, 6.2.3

[284] Marek Piotr Michalowski. *Rhythmic human-robot social interaction*. Carnegie Mellon University, 2010. 6.1, 6.2.3

[285] Byung-Cheol Min, Aaron Steinfeld, and M. Bernardine Dias. How would you describe assistive robots to people who are blind or low vision? In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts*, HRI'15 Extended Abstracts, page 91–92, New York, NY, USA, 2015. Association for Computing Machinery. ISBN 9781450333184. doi: 10.1145/2701973.2702002. URL https://doi.org/10.1145/2701973.

2702002. 3.7.1, 3.8

[286] Julie Avril Minich. Enabling whom? critical disability studies now. *Lateral*, 5(1), 2016. 1.2, 2.1.2

[287] Thomas J Misa, Philip Brey, and Andrew Feenberg. *Modernity and technology*. MIT press, 2003. 4.1

[288] Akeem Modeste-James, T'Shana McClain, and Michele Hanna. "the system isn't set up for us": Stories of young black women's mental health journey. *Women's Health*, 20:17455057241297106, 2024. 7.1, 7.4.1

[289] Shakir Mohamed, Marie-Therese Png, and William Isaac. Decolonial ai: Decolonial theory as sociotechnical foresight in artificial intelligence. *Philosophy & Technology*, 33(4):659–684, 2020. 8.3

[290] Dermont Moran. *Introduction to phenomenology*. routledge, 2002. 2.1.1

[291] Cecily Morrison, Edward Cutrell, Anupama Dhareshwar, Kevin Doherty, Anja Thieme, and Alex Taylor. Imagining artificial intelligence applications with people with visual disabilities using tactile ideation. In *Proceedings of the 19th international acm sigaccess conference on computers and accessibility*, pages 81–90, 2017. 4.3.2

[292] Alexander Mörtl, Tamara Lorenz, and Sandra Hirche. Rhythm patterns interaction-synchronization behavior for human-robot joint action. *PloS one*, 9(4):e95195, 2014. 6.1, 6.2.3

[293] Michael Muhammad, Nina Wallerstein, Andrew L Sussman, Magdalena Avila, Lorenda Belone, and Bonnie Duran. Reflections on researcher identity and power: The impact of positionality on community based participatory research (cbpr) processes and outcomes. *Critical sociology*, 41(7-8):1045–1063, 2015. 7.3.2

[294] Nancy Nainis, Judith A Paice, Julia Ratner, James H Wirth, Jerry Lai, and Susan Shott. Relieving symptoms in cancer: innovative use of art therapy. *Journal of pain and symptom management*, 31(2):162–169, 2006. 5.3.1

[295] Adit Nair, Roshan Mathew, Zihao Mei, Rezylle Milallos, Pratheep Kumar Chelladurai, and Tae Oh. Investigating the user experience and challenges of food delivery applications for the blind and visually impaired. In *Proceedings of the 25th International Conference on Mobile Human-Computer Interaction*, pages 1–6, 2023. 4.1, 4.2.1, 4.4.1, 4.5

[296] Amal Nanavati, Xiang Zhi Tan, Joe Connolly, and Aaron Steinfeld. Follow the robot: Modeling coupled human-robot dyads during navigation. In *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 3836–3843, 2019. doi: 10.1109/IROS40897.2019.8967656. 3.7.1, 3.8

[297] DISCO Network. *Technoskepticism: Between possibility and refusal*. Stanford University Press, 2025. 1.2, 7.2.3, 7.3.3

[298] Lesley-Ann Noel, Adolfo Ruiz, Frederick MC van Amstel, Victor Udoewa, Neeta Verma, Nii Kommey Botchway, Arvind Lodaya, and Shalini Agrawal. Pluriversal futures for design education. *She Ji: The Journal of Design, Economics, and Innovation*, 9(2):179–196, 2023. 1.2, 1.6, 4.1, 4.3, 4.5.2, 8.1.3, 8.2.2

[299] Seri Nonaka, Kenji Inoue, Tatsuo Arai, and Yasushi Mae. Evaluation of human sense of security for coexisting robots using virtual reality. 1st report: evaluation of pick and place motion of humanoid robots. In *IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA'04. 2004*, volume 3, pages 2770–2775. IEEE, 2004. 3.2.3

[300] nternational Organization for Standardization (ISO). 3.7 service robot, Jun 2026. 1.1, 1.4.2

[301] Claudia Núñez-Pacheco. Dialoguing with tangible traces: A method to elicit autoethnographic narratives. In *Proceedings of the Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction*, pages 1–14, 2022. 2.1.3, 7.2.3, 7.3.3, 7.3.4

[302] Denise N Obinna. Essential and undervalued: health disparities of african american women in the covid-19 era. *Ethnicity & health*, 26(1):68–79, 2021. 2, 1

[303] National Institute of Mental Health. Mental illness, Sep 2024. URL `https://www.nimh.nih.gov/health/statistics/mental-illness`. 5.2

[304] City of Pittsburgh. City of pittsburgh cdbg fy24 income limits. `https://www.pittsburghpa.gov/files/assets/city/v/1/omb/documents/resources-for-subrecipients/lmc-py2024-income-limits.pdf`, 2024. 4.3.2

[305] Minnesota Department of Transportation. dot.state.mn.us. `https://dot.state.mn.us/automated/docs/personal-delivery-device-white-paper.pdf`, 2021. 4.1, 4.2.1

[306] Office of Minority Health. Mental and behavioral health - Black/African Americans. U.S. Department of Health and Human Services, 2024. URL `https://minorityhealth.hhs.gov/mental-and-behavioral-health-blackafrican-americans`. Accessed: 2026-03-30. 7.1

[307] Ihudiya Finda Ogbonnaya-Ogburu, Angela DR Smith, Alexandra To, and Kentaro Toyama. Critical race theory for hci. In *Proceedings of the 2020 CHI conference on human factors in computing systems*, pages 1–16, 2020. 7.4.6

[308] Makoto Okamoto. Possibility of participatory design. In *Human Centered Design: First International Conference, HCD 2009, Held as Part of HCI International 2009, San Diego, CA, USA, July 19-24, 2009 Proceedings 1*, pages 888–893. Springer, 2009. 3.2.2

[309] Teresa K O'Leary, Elizabeth Stowell, Everlyne Kimani, Dhaval Parmar, Stefan Olafsson, Jessica Hoffman, Andrea G Parker, Michael K Paasche-Orlow, and Timothy Bickmore. Community-based cultural tailoring of virtual agents. In *proceedings of the 20th ACM international conference on intelligent virtual agents*, pages 1–8, 2020. 7.2.1

[310] Teresa K O'Leary, Varshini Batti, Shannon Dhindsa, Vignesh Hari Krishnan, Lauren Wilcox, Cheryl L Woods-Giscombe, Chyrell D Bellamy, and Terika McCall. " it was empowering": Care pathways a novel culturally informed inspiration card game for community-engaged co-design with black american women and clinicians. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*, pages 1–8, 2025. 5.3.4, 7.1, 7.3.1

[311] Kenneth Olmstead Olmstead. Nearly half of americans use digital voice assistants, mostly on their smartphones, Dec 2017. URL https://www.pewresearch.org/short-reads/2017/12/12/nearly-half-of-americans-use-digital-voice-assistants-mostly-on-their-smartphones/?gad_source=1&gad_campaignid=23853897313&gbraid=0AAAAA-ddO9FN4bcC7JLmPMIbH1soVkH8L&gclid=Cj0KCQjw2_TQBhCnARIsAF3-XhzwkzBuT5-JYmXlV9e4OlJJTCpht1J9DGyLLOA9P5C4CIUh0C_Obw8aAhWiEALw_wcB. 5.3.2

[312] World Health Organization. *International classification of functioning, disability, and health: Children & youth version: ICF-CY.* World Health Organization, 2007. 1.4.1

[313] World Health Organization. Mental health, Jun 2022. URL https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response. 5.2

[314] World Health Organization et al. Health topics: Disability, 2021. 1.4.4

[315] Maria Orphanidou, Irini Kadianaki, and Cliodhna O'Connor. Depression as an embodied experience: Identifying the central role of the body in meaning-making and identity processes. *Qualitative Health Research*, 33(6):509–520, 2023. 5.1

[316] Anastasia K Ostrowski. *How Do We Design Robots Equitably? Engaging Design Justice, Design Fictions, and Co-Design in Human-Robot Interaction Design and Policymaking Processes*. Massachusetts Institute of Technology, 2023. 2.2.2, 1, 2, 8.2.2

[317] Anastasia K Ostrowski and Cynthia Breazeal. Design justice for robot design and policy making. In *2022 17th ACM/IEEE international conference on human-robot interaction (HRI)*, pages 1170–1172. IEEE, 2022. 3.7.1

[318] Anastasia K Ostrowski, Cynthia Breazeal, and Hae Won Park. Long-term co-design

guidelines: empowering older adults as co-designers of social robots. In *2021 30th IEEE international conference on robot & human interactive communication (RO-MAN)*, pages 1165–1172. IEEE, 2021. 1.2, 2.1.4, 2.2.2, 7.4.5, 8.1.3, 8.3

[319] Anastasia K Ostrowski, Christina N Harrington, Cynthia Breazeal, and Hae Won Park. Personal narratives in technology design: the value of sharing older adults' stories in the design of social robots. *Frontiers in Robotics and AI*, 8:716581, 2021. 2.2.2, 2.2.3, 1, 8.1.3

[320] Anastasia K Ostrowski, Cynthia Breazeal, and Hae Won Park. Mixed-method long-term robot usage: Older adults' lived experience of social robots. In *2022 17th ACM/IEEE international conference on human-robot interaction (HRI)*, pages 33–42. IEEE, 2022. 1.2, 2.1.4, 2.2.2, 1

[321] Anastasia K Ostrowski, Cynthia Breazeal, and Hae Won Park. How do older adults engage as robot co-designers? rapid prototyping supported by lived experiences with technology. *Expanding the frontiers of design: A blessing or a curse?*, page 193, 2022. 2.2.2

[322] Anastasia K Ostrowski, Jenny Zhang, Cynthia Breazeal, and Hae Won Park. Promising directions for human-robot interactions defined by older adults. *Frontiers in Robotics and AI*, 11:1289414, 2024. 5.3.4

[323] Elisa Pamelia. Therapeutic art-making and art therapy: Similarities and differences and a resulting framework. 2015. 5.3.1

[324] Lenore K. Pedicord. Nsf supports efforts to emphasize the ability in 'disability'. https://www.nsf.gov/science-matters/nsf-supports-efforts-emphasize-ability-disability, 2024. 1.1, 1.4.4

[325] Joseph M Pierre, Ben Gaeta, Govind Raghavan, and Karthik V Sarma. "you're not crazy": A case of new-onset ai-associated psychosis. *Innovations in Clinical Neuroscience*, 22(10-12):11, 2025. 7.2.1

[326] Cynthia J Price and Carole Hooven. Interoceptive awareness skills for emotion regulation: Theory and approach of mindful awareness in body-oriented therapy (mabt). *Frontiers in psychology*, 9:335233, 2018. 5.3.1

[327] Sarah M Rabbitt, Alan E Kazdin, and Brian Scassellati. Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use. *Clinical psychology review*, 35:35–46, 2015. 5.3.2, 5.3.3, 7.2.1

[328] Jensine Raihan. The colonial legacy of the human in human-computer interaction: Implications for critical design approaches. In *Proceedings of the sixth decennial Aarhus conference: Computing X Crisis*, pages 140–152, 2025. 1.2, 2.2.2, 2.2.3

[329] Nusha Ramsoondar, Alex Anawati, and Erin Cameron. Racism as a determinant of health and health care: Rapid evidence narrative from the safe for health institutions

project. *Canadian Family Physician*, 69(9):594–598, 2023. 5.4

[330] Pramila Rani, Nilanjan Sarkar, Craig A Smith, and Leslie D Kirby. Anxiety detecting robotic system–towards implicit human-robot collaboration. *Robotica*, 22(1):85–95, 2004. 3.2.3

[331] Marlou Rasenberg, Asli Özyürek, and Mark Dingemanse. Alignment in multimodal interaction: An integrative framework. *Cognitive science*, 44(11):e12911, 2020. 6.1, 6.2.2, 6.5.3

[332] Amy Leigh Rathbone, Laura Clarry, and Julie Prescott. Assessing the efficacy of mobile health apps using the basic principles of cognitive behavioral therapy: systematic review. *Journal of medical Internet research*, 19(11):e399, 2017. 5.3.2

[333] Arghya Ray, Amandeep Dhir, Pradip Kumar Bala, and Puneet Kaur. Why do people use food delivery apps (fda)? a uses and gratification theory perspective. *Journal of retailing and consumer services*, 51:221–230, 2019. 4.1, 4.5

[334] Dabbala Rajagopal Reddy. *Speech recognition: invited papers presented at the 1974 IEEE symposium*. Elsevier, 1975. 6.3.2

[335] Samantha Reig, Michal Luria, Janet Z Wang, Danielle Oltman, Elizabeth Jeanne Carter, Aaron Steinfeld, Jodi Forlizzi, and John Zimmerman. Not some random agent: Multi-person interaction with a personalizing service robot. In *Proceedings of the 2020 ACM/IEEE international conference on human-robot interaction*, pages 289–297, 2020. 7.4.5

[336] Jakob Reinhardt, Aaron Pereira, Dario Beckert, and Klaus Bengler. Dominance and movement cues of robot motion: A user study on trust and predictability. In *2017 IEEE international conference on systems, man, and cybernetics (SMC)*, pages 1493–1498. IEEE, 2017. 6.5.2

[337] Laurel D Riek, Philip C Paul, and Peter Robinson. When my robot smiles at me: Enabling human-robot rapport via real-time head gesture mimicry. *Journal on Multimodal User Interfaces*, 3:99–108, 2010. 6.1, 6.2.3

[338] Jeffrey J Risher, Dana E Harrison, and Stephen A LeMay. Last mile non-delivery: consumer investment in last mile infrastructure. *Journal of marketing theory and practice*, 28(4):484–496, 2020. 4.4.1, 4.4.2

[339] Lee N Robins and Rumi K Price. Adult disorders predicted by childhood conduct problems: results from the nimh epidemiologic catchment area project. *Psychiatry*, 54(2):116–132, 1991. 7.1

[340] Hayley Robinson, Bruce MacDonald, Ngaire Kerse, and Elizabeth Broadbent. The psychosocial effects of a companion robot: a randomized controlled trial. *Journal of the American Medical Directors Association*, 14(9):661–667, 2013. 5.3.3

[341] Agility Robotics. Digit: Curb to doorstep delivery. https://www.youtube.

com/watch?v=CUhuhIeQNos, 2019. 4.3.2

[342] Wendy A Rogers, Travis Kadylak, and Megan A Bayles. Maximizing the benefits of participatory design for human–robot interaction research with older adults. *Human factors*, 64(3):441–450, 2022. 3.2.1

[343] Mary Beth Rosson and John M Carroll. Scenario-based design. In *The human-computer interaction handbook*, pages 1067–1086. CRC Press, 2007. 3.2.2

[344] Matteo Rubagotti, Inara Tusseyeva, Sara Baltabayeva, Danna Summers, and Anara Sandygulova. Perceived safety in physical human–robot interaction—a survey. *Robotics and Autonomous Systems*, 151:104047, 2022. 3.2.3

[345] Manaswi Saha, Michael Saugstad, Hanuma Teja Maddali, Aileen Zeng, Ryan Holland, Steven Bower, Aditya Dash, Sage Chen, Anthony Li, Kotaro Hara, et al. Project sidewalk: A web-based crowdsourcing tool for collecting sidewalk accessibility data at scale. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–14, 2019. 4.5.1

[346] Nuzhah Gooda Sahib, Tony Stockman, Anastasios Tombros, and Oussama Metatla. Participatory design with blind users: A scenario-based approach. In *IFIP TC13 International Conference on Human-Computer Interaction*, 2013. URL https://api.semanticscholar.org/CorpusID:18552803. 3.2.2, 3.4

[347] Nuzhah Gooda Sahib, Tony Stockman, Anastasios Tombros, and Oussama Metatla. Participatory design with blind users: a scenario-based approach. In *IFIP Conference on Human-Computer Interaction*, pages 685–701. Springer, 2013. 4.3.2, 8.1.3

[348] Charalampos Saitis and Kyriaki Kalimeri. Multimodal classification of stressful environments in visually impaired mobility using eeg and peripheral biosignals. *IEEE Transactions on Affective Computing*, 12(1):203–214, 2018. 3.1, 3.8.3

[349] Gayle Salamon. What's critical about critical phenomenology? *Puncta*, 1(1):8–17, 2018. 2.1.2

[350] Carrie Sandahl. Black man, blind man: Disability identity politics and performance. *Theatre Journal*, 56(4):579–602, 2004. 3.8.4

[351] Elizabeth B-N Sanders. From user-centered to participatory design approaches. In *Design and the social sciences*, pages 18–25. CRC Press, 2002. 2.1.3, 8.1.3

[352] Elizabeth B-N Sanders and Pieter Jan Stappers. Probes, toolkits and prototypes: three approaches to making in codesigning. *CoDesign*, 10(1):5–14, 2014. 3.4, 4.3.2, 4.3.2, 7.2.1, 7.3.4

[353] Jürgen Sauer, Katrin Seibel, and Bruno Rüttinger. The influence of user expertise and prototype fidelity in usability tests. *Applied ergonomics*, 41(1):130–140, 2010. 1.2, 8.1.3

[354] Peter Schaldenbrand, Gaurav Parmar, Jun-Yan Zhu, James McCann, and Jean Oh.

CoFRIDA: Self-supervised fine-tuning for human-robot co-painting. *arXiv preprint arXiv:2402.13442*, 2024. 6.1, 6.2.3

[355] Sami Schalk. *Bodyminds reimagined:(Dis) ability, race, and gender in Black women's speculative fiction*. Duke University Press, 2018. 7.2.3

[356] Matthias Schmidmaier, Jonathan Rupp, Darina Cvetanova, and Sven Mayer. Perceived empathy of technology scale (PETS): Measuring empathy of systems toward the user. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*, pages 1–18, 2024. 6.3.3, 6.5.1

[357] Jonas Schmidtler, Klaus Bengler, Fotios Dimeas, and Alexandre Campeau-Lecours. A questionnaire for the evaluation of physical assistive devices (quead): Testing usability and acceptance in physical human-robot interaction. In *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, pages 876–881, 2017. doi: 10.1109/SMC.2017.8122720. 3.4, 3.8.3

[358] Donald A Schön. *The reflective practitioner: How professionals think in action*. Routledge, 2017. 2.1.3

[359] Karin Alice Schouten, Gerrit J de Niet, Jeroen W Knipscheer, Rolf J Kleber, and Giel JM Hutschemaekers. The effectiveness of art therapy in the treatment of traumatized adults: A systematic review on art therapy and trauma. *Trauma, violence, & abuse*, 16(2):220–228, 2015. 5.3.1

[360] Katie Seaborn, Giulia Barbareschi, and Shruti Chandra. Not only weird but "uncanny"? a systematic review of diversity in human–robot interaction research. *International Journal of Social Robotics*, 15(11):1841–1870, 2023. 1.1, 1.2, 2.1.4, 5.3.4

[361] R Semin and JT Cacioppo. Synchronization, coordination, and co-regulation. *Grounding social cognition*, pages 119–128, 2006. 5.3.1

[362] Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph'Jofish' Kaye. Reflective design. In *Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility*, pages 49–58, 2005. 2.1.3, 2.2.3

[363] Suraj Singh Senjam. Smartphones as assistive technology for visual impairment. *Eye*, 35(8):2078–2080, 2021. 4.3.2

[364] Pamela Seron, María-Jose Oliveros, Ruvistay Gutierrez-Arias, Rocío Fuentes-Aspe, Rodrigo C Torres-Castro, Catalina Merino-Osorio, Paula Nahuelhual, Jacqueline Inostroza, Yorschua Jalil, Ricardo Solano, et al. Effectiveness of telerehabilitation in physical therapy: a rapid overview. *Physical therapy*, 101(6):pzab053, 2021. 5.3.2

[365] Tom Shakespeare. *Disability rights and wrongs*. Routledge, 2006. 1.4.1

[366] Ntozake Shange. *For colored girls who have considered suicide when the rainbow is enuf*. Simon and Schuster, 1997. 7.3.3

[367] Gal Sheppes, Gaurav Suri, and James J Gross. Emotion regulation and psychopathology. *Annual review of clinical psychology*, 11(1):379–405, 2015. 5.3.1

[368] Zhonghao Shi, Han Chen, Anna-Maria Velentza, Siqi Liu, Nathaniel Dennler, Allison O'Connell, and Maja Mataric. Evaluating and personalizing user-perceived quality of text-to-speech voices for delivering mindfulness meditation with different physical embodiments. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*, pages 516–524, 2023. 5.3.3

[369] Katherine Shih, Abena Boadi-Agyemang, Elizabeth Carter, and Aaron Steinfeld. A multi-method investigation of guide robot characteristics for blind and low-vision users. *ACM Transactions on Human-Robot Interaction*, 15(1):1–22, 2025. 3, 3.1, 3.4, 4.4.2

[370] Michihiro Shimada, Kazunori Yamauchi, Takashi Minato, Hiroshi Ishiguro, and Shoji Itakura. Studying the influence of the chameleon effect on humans using an android. In *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 767–772. IEEE, 2008. 6.2.3

[371] Hyorim Shin, Junho Choi, and Changhoon Oh. Delivering the future: Understanding user perceptions of delivery robots. *Proceedings of the ACM on Human-Computer Interaction*, 8(CSCW1):1–24, 2024. 4.2.1, 4.3.3

[372] JeongPil Shin, DongHan Son, YoungHwan Kim, and TaeWon Seo. Design exploration and comparative analysis of tail shape of tri-wheel-based stair-climbing robotic platform. *Scientific Reports*, 12(1):19488, 2022. 4.4.5

[373] Kevin Shockley, Daniel C Richardson, and Rick Dale. Conversation and coordinative structures. *Topics in Cognitive Science*, 1(2):305–319, 2009. 5.4

[374] Snehesh Shrestha, Yantian Zha, Saketh Banagiri, Ge Gao, Yiannis Aloimonos, and Cornelia Fermüller. Natsgld: A dataset with speech, gesture, logic, and demonstration for robot learning in natural human-robot interaction. In *2025 20th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 1093–1098. IEEE, 2025. 4.5.1

[375] Richard Shusterman. *Body consciousness: A philosophy of mindfulness and somaesthetics*. Cambridge University Press, 2008. 2.1.3, 7.2.3, 7.3.3, 7.3.3

[376] Loïck Simon, Clément Guérin, Philippe Rauffet, Christine Chauvin, and Éric Martin. How humans comply with a (potentially) faulty robot: Effects of multidimensional transparency. *IEEE Transactions on Human-Machine Systems*, 53(4):751–760, 2023. doi: 10.1109/THMS.2023.3273773. 4.4.4

[377] Barinder Singh. The therapeutic effects of art making in patients with cancer. *The Arts in Psychotherapy*, 38(3):160–163, 2011. 5.3.1

[378] Linda Tuhiwai Smith. Decolonizing methodologies: Research and indigenous

peoples. 2021. 2.2.3

[379] Daniel G Solórzano and Tara J Yosso. Critical race methodology: Counter-storytelling as an analytical framework for education research. *Qualitative inquiry*, 8(1):23–44, 2002. 4.3.2, 4.4.7, 8.1.3

[380] Katta Spiel. The bodies of tei–investigating norms and assumptions in the design of embodied interaction. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*, pages 1–19, 2021. 7.2.3

[381] Katta Spiel and Robin Angelini. Expressive bodies engaging with embodied disability cultures for collaborative design critiques. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*, pages 1–6, 2022. 7.2.3

[382] Micol Spitale, Minja Axelsson, and Hatice Gunes. Robotic mental well-being coaches for the workplace: An in-the-wild study on form. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*, pages 301–310, 2023. 7.3.3

[383] Robert L Spitzer, Kurt Kroenke, Janet BW Williams, and Bernd Löwe. A brief measure for assessing generalized anxiety disorder: the gad-7. *Archives of internal medicine*, 166(10):1092–1097, 2006. 7.3.1

[384] Phoebe A Staab, A Jess Williams, Mackenzie DA Robertson, and Petr Slovak. “can you be with that feeling?”: Extending design strategies for interoceptive awareness for the context of mental health. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, pages 1–21, 2024. 7.2.3

[385] Samantha Stedtler. Social injustice, group membership and epistemic trust in robots. In *Robo-Identity Workshop 3, HRI'24: Robo-Identity: Designing for Identity in the Shared World*, pages 1–4, 2024. 7.4.6, 7.5

[386] Catherine Knight Steele. Digital black feminism. In *Digital black feminism*. New York University Press, 2021. 7.2.3

[387] Aaron Steinfeld, Odest Chadwicke Jenkins, and Brian Scassellati. The Oz of Wizard: Simulating the human for interaction research. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pages 101–108, 2009. 3.2.1, 7.4.6

[388] Aaron Steinfeld, Jordana L Maisel, and Edward Steinfeld. *Accessible public transportation: designing service for riders with disabilities*. Routledge, 2017. 4.2.1

[389] Edward Steinfeld and Jordana Maisel. *Universal design: Creating inclusive environments*. John Wiley & Sons, 2012. 1.1, 2.2.1

[390] Darja Stoeva, Andreas Kriegler, and Margrit Gelautz. Body movement mirroring and synchrony in human-robot interaction. *ACM Transactions on Human-Robot*

Interaction, 2024. 5.3.3, 6.1, 6.2.2, 6.2.3

[391] Brandi Stone. Serving in black spaces of the institution: A decolonial black feminist autoethnography. *Agenda*, 37(2):121–133, 2023. 7.2.3

[392] Sharon Dale Stone. The situated nature of disability. In *Transactional perspectives on occupation*, pages 95–106. Springer, 2012. 1.4.1

[393] Cella M Sum, Franchesca Spektor, Rahaf Alharbi, Leya Breanna Baltaxe-Admony, Erika Devine, Hazel Anneke Dixon, Jared Duval, Tessa Eagle, Frank Elavsky, Kim Fernandes, et al. Challenging ableism: A critical turn toward disability justice in hci. *XRDS: Crossroads, The ACM Magazine for Students*, 30(4):50–55, 2024. 3.8.4, 4.1, 4.2.2

[394] Cella M Sum, Jiayin Zhi, Amil NT Cook, Patrick James Cooper, Arturo Lozano, TJ Johnson, Jason Perez, Rayid Ghani, Michael Skirpan, Motahhare Eslami, et al. " you're in a ferrari. i'm waiting for the bus": Confronting tensions in community-university partnerships. *Proceedings of the ACM on Human-Computer Interaction*, 9(2):1–28, 2025. 3.8.4

[395] David Swann. Nhs at home: Using lego serious play to capture service narratives and envision future healthcare products. *INCLUDE 2011 Proceedings*, 2011. 4.3.2

[396] Starship Technologies. An audio description of a starship robot. https://www.youtube.com/watch?v=ZwJDhX9g3KY, 2024. 4.3.2

[397] Starship Technologies. Autonomous robots accessibility — starship.xyz. https://www.starship.xyz/autonomous-robots-accessibility/, 2025. 4.1

[398] Deborah Theodoros, Trevor Russell, and R Latifi. Telerehabilitation: current perspectives. *Studies in health technology and informatics*, 131(1):191–210, 2008. 5.3.2

[399] Madina Tlostanova. On decolonizing design. *Design Philosophy Papers*, 15(1): 51–61, 2017. 1.6, 2.2.3, 4.1, 4.2.2

[400] Alexandra To, Angela DR Smith, Dilruba Showkat, Adinawa Adjagbodjou, and Christina Harrington. Flourishing in the everyday: Moving beyond damage-centered design in hci for bipoc communities. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, pages 917–933, 2023. 7.2.3

[401] Jordi Tost, Rahel Flechtner, Rahel Maué, and Frank Heidmann. Caring for a companion as a form of self-care. exploring the design space for irritating companion technologies for mental health. In *Proceedings of the 13th Nordic Conference on Human-Computer Interaction*, pages 1–15, 2024. 7.2.3

[402] Emily Tseng and Calvin A Liang. " chat, should i leave him?" risks, rewards, and roles for ai in relationship advice. In *Proceedings of the 2026 CHI Conference on*

Human Factors in Computing Systems, pages 1–19, 2026. 7.4.4, 7.4.5, 7.5

[403] Elizabeth Dori Tunstall. Decolonizing design innovation: Design anthropology, critical anthropology, and indigenous knowledge. In *Design anthropology*, pages 232–250. Routledge, 2020. 1.6

[404] Stephanie Valencia, Michal Luria, Amy Pavel, Jeffrey P Bigham, and Henny Admoni. Co-designing socially assistive sidekicks for motion-based aac. In *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*, pages 24–33, 2021. 4.5.1

[405] Dannyelle Valente, Anne Theurel, and Edouard Gentaz. The role of visual experience in the production of emotional facial expressions by blind people: A review. *Psychonomic bulletin & review*, 25(2):483–497, 2018. 3.8.3

[406] Eveline van Zeeland. Design principles of the pluriversal design paradigm. 2024. 1.6, 4.1, 4.3, 4.5.2

[407] Briana Vecchione and Ranjit Singh. Artificial intelligence is mental: Evaluating the role of large-language models in supporting mental health and well-being. *Big Data & Society*, 12(4):20539517251383884, 2025. 7.5

[408] Paola Velasco-Herrejón, Thomas Bauwens, and Martin Calisto Friant. Challenging dominant sustainability worldviews on the energy transition: Lessons from indigenous communities in mexico and a plea for pluriversal technologies. *World Development*, 150:105725, 2022. 1.2, 4.1

[409] Ralf Vetter, Anna Dobrosovestnova, Helena Anna Frijns, Laura Vogel, Katharina Brunnmayr, and Christopher Frauenberger. From care practices to speculative vignettes–design considerations for robots in good care. *Frontiers in Robotics and AI*, 11:1347367, 2024. 7.2.1

[410] Dace Visnola, Dagmāra Sprūdža, Mārīte Ārija Baķe, and Anita Piķe. Effects of art therapy on stress and anxiety of employees. In *Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences.*, volume 64, pages 85–91, 2010. 5.3.1

[411] Liyang Wang, Jinxin Zhao, and Liangjun Zhang. Navdog: Robotic navigation guide dog via model predictive control and human-robot modeling. In *Proceedings of the 36th Annual ACM Symposium on Applied Computing*, SAC '21, page 815–818, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450381048. doi: 10.1145/3412841.3442098. 3.1

[412] Qiu-Yue Wang and Dong-Mei Li. Advances in art therapy for patients with dementia. *Chinese Nursing Research*, 3(3):105–108, 2016. 5.3.1

[413] Courtney Ward-Sutton, Natalie F Williams, Corey L Moore, and Edward O Manyibe. Assistive technology access and usage barriers among african americans with

disabilities: A review of the literature and policy. *Journal of applied rehabilitation counseling*, 51(2):115, 2020. 3.8.4

[414] Akash R Wasil, Emma H Palermo, Lorenzo Lorenzo-Luaces, and Robert J DeRubeis. Is there an app for that? a review of popular apps for depression, anxiety, and well-being. *Cognitive and Behavioral Practice*, 29(4):883–901, 2022. 5.3.2

[415] E Kate Webb, Sierra E Carter, Kerry J Ressler, Negar Fani, and Nathaniel G Harnett. The neurophysiological consequences of racism-related stressors in black americans. *Neuroscience & Biobehavioral Reviews*, 161:105638, 2024. 5.4, 7.2.2

[416] Yuanlong Wei, Xiangxin Kou, and Min Cheol Lee. A new vision and navigation research for a guide-dog robot system in urban system. In *2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, pages 1290–1295, 2014. doi: 10.1109/AIM.2014.6878260. 3.1

[417] David Weinberg, Healy Dwyer, Sarah E Fox, and Nikolas Martelaro. Sharing the sidewalk: Observing delivery robot interactions with pedestrians during a pilot in pittsburgh, pa. *Multimodal Technologies and Interaction*, 7(5):53, 2023. 4.2.1

[418] Lauren White, Alison Buxton, Kirsty Liddiard, Dan Goodley, Saman Qarni, Elizabeth Jansen, Harry Gordon, and Sarah Gillard. Disabled young people as researchers, designers and makers: aligning makerspaces, co-production and critical disability studies. *Journal of Disability Studies in Education*, 1(aop):1–25, 2025. 1.2

[419] World Health Organization (WHO). Mental disorders. https://www.who.int/news-room/fact-sheets/detail/mental-disorders. [Accessed 30-10-2025]. 5.2

[420] Danielle Wilde, Anna Vallgårda, and Oscar Tomico. Embodied design ideation methods: Analysing the power of estrangement. In *Proceedings of the 2017 CHI conference on human factors in computing systems*, pages 5158–5170, 2017. 8.1.3

[421] Rua M Williams. I, misfit: Empty fortresses, social robots, and peculiar relations in autism research. *Techne: Research in Philosophy & Technology*, 25(3), 2021. 1.2, 5.3.2

[422] Rua M Williams and Juan E Gilbert. "nothing about us without us" transforming participatory research and ethics in human systems engineering. In *Advancing diversity, inclusion, and social justice through human systems engineering*, pages 113–134. CRC Press, 2019. 1.2, 7.2.1

[423] Rua Mae Williams, Louanne Boyd, and Juan E Gilbert. Counterventions: a reparative reflection on interventionist hci. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–11, 2023. 1.2, 2.2.2, 2.2.3

[424] Bess Williamson. The people's sidewalks, Jun 2012. URL https://boomcalifornia.org/2012/06/26/the-peoples-sidewalks/. 1.1

[425] Shawn Wilson. *Research is ceremony: Indigenous research methods*. Fernwood publishing, 2020. 7.2.3

[426] Katie Winkle, Emmanuel Senft, and Séverin Lemaignan. Leador: A method for end-to-end participatory design of autonomous social robots. *Frontiers in Robotics and AI*, 8:704119, 2021. 1.2

[427] Katie Winkle, Donald McMillan, Maria Arnelid, Katherine Harrison, Madeline Balaam, Ericka Johnson, and Iolanda Leite. Feminist human-robot interaction: Disentangling power, principles and practice for better, more ethical hri. In *Proceedings of the 2023 ACM/IEEE international conference on human-robot interaction*, pages 72–82, 2023. 1.2, 2.2.3, 4.2.2

[428] Jacob O Wobbrock. Situationally-induced impairments and disabilities. In *Web Accessibility: A Foundation for Research*, pages 59–92. Springer, 2019. 1.4.1

[429] Jacob O Wobbrock, Shaun K Kane, Krzysztof Z Gajos, Susumu Harada, and Jon Froehlich. Ability-based design: Concept, principles and examples. *ACM Transactions on Accessible Computing (TACCESS)*, 3(3):1–27, 2011. 2.2.1, 5.3.2

[430] Cheryl L Woods-Giscombé. Superwoman schema: African american women's views on stress, strength, and health. *Qualitative health research*, 20(5):668–683, 2010. 7.1, 7.3.3

[431] Anon Ymous, Katta Spiel, Os Keyes, Rua M Williams, Judith Good, Eva Hornecker, and Cynthia L Bennett. " i am just terrified of my future"—epistemic violence in disability related technology research. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–16, 2020. 1.1, 1.2, 1.4.3, 3.8.4, 4.2.2, 8.1.3

[432] Xinyan Yu, Marius Hoggenmüller, Tram Thi Minh Tran, Yiyuan Wang, and Martin Tomitsch. Understanding the interaction between delivery robots and other road and sidewalk users: A study of user-generated online videos. *ACM Transactions on Human-Robot Interaction*, 13(4):1–32, 2024. 4.2.1

[433] Maryam Zahabi, Xi Zheng, Azima Maredia, and Farzaneh Shahini. Design of navigation applications for people with disabilities: A review of literature and guideline formulation. *International Journal of Human–Computer Interaction*, 39 (14):2942–2964, 2023. 2.1.1, 3.2.1

[434] Dan Zahavi. *Phenomenology: the basics*. Routledge, 2025. 2.1.1, 2.1.1, 2.1.1, 2.1.1

[435] Limin Zeng, Björn Einert, Alexander Pitkin, and Gerhard Weber. Hapticrein: Design and development of an interactive haptic rein for a guidance robot. In *Computers Helping People with Special Needs: 16th International Conference, ICCHP 2018, Linz, Austria, July 11-13, 2018, Proceedings, Part II 16*, pages 94–101. Springer, 2018. 3.7.1

[436] Minghong Zhang, Jiakun Pei, and Mirna Zordan. Robots that make you feel: Understanding perceptions of robotic biofeedback for emotion regulation. In *Proceedings of the Twentieth International Conference on Tangible, Embedded, and Embodied Interaction*, pages 1–7, 2026. 5.3.3

[437] Yichen Zhou, Mingxing Wen, Xun Chen, Chunyang Zhao, Jiajie Guo, Jun Zhang, Yufeng Yue, and Yingchong Ma. Towards safe and efficient last-mile delivery: A multi-modal socially aware navigation framework for autonomous robots on pedestrian-crowded sidewalks. In *2024 IEEE International Conference on Cybernetics and Intelligent Systems (CIS) and IEEE International Conference on Robotics, Automation and Mechatronics (RAM)*, pages 392–398. IEEE, 2024. 4.2.1

[438] Yifei Zhu, Ruchen Wen, and Tom Williams. Robots for social justice (r4sj): Toward a more equitable practice of human-robot interaction. In *Proceedings of the 2024 ACM/IEEE International Conference on Human-Robot Interaction*, pages 850–859, 2024. 4.2.2

[439] Michael J Zvolensky, Justin M Shepherd, Bryce K Clausen, Brooke Y Kauffman, Luke Heggeness, and Lorra Garey. Anxiety sensitivity among non-hispanic black adults: Relations to mental health and psychosomatic states. *Journal of racial and ethnic health disparities*, 10(2):751–760, 2023. 7.1

[440] Douglas Zytko, Pamela J. Wisniewski, Shion Guha, Eric PS Baumer, and Min Kyung Lee. Participatory design of ai systems: opportunities and challenges across diverse users, relationships, and application domains. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*, pages 1–4, 2022. 1.2