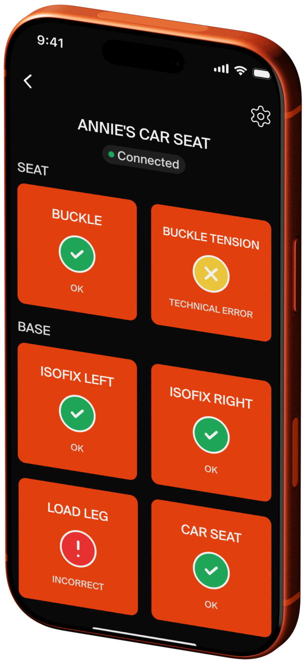

Accessibility in Motion

Developing context-specific accessibility recommendations and re-designing the Thule mobile application

Master's thesis in Computer science and engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Gothenburg, Sweden 2026

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Abstract

Mobile applications are increasingly used in dynamic environments, yet existing accessibility frameworks, such as WCAG 2.2, primarily address static use cases. This Master's thesis investigates the limitations of current guidelines when faced with Situationally Induced Impairments and Disabilities (SIIDs), including screen glare and reduced dexterity from physical multitasking. In collaboration with Thule Sweden AB, the study employs a Research through Design methodology within a Double Diamond framework. By combining contextual inquiry, general and targeted surveys, and heuristic evaluations, the research identifies critical pain points in active mobile usage. The project culminates in the formulation of 14 context-specific accessibility recommendations and the iterative development of a high-fidelity mobile prototype. This proposed final design features an "Active Mode", an interface variation that removes non-essential visuals to prioritize cognitive clarity. The findings demonstrate that digital accessibility in high-motion environments relies heavily on functional minimalism, ergonomic adaptability, and error tolerance, ensuring usability supersedes traditional aesthetics.

Keywords: Interaction design, UI design, UX design, user-centered design, design process, prototyping, Accessibility, SIIDs, WCAG.

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Benjamin & Enes, Gothenburg, 2026-06-02

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1

Introduction

The modern smartphone has evolved beyond its initial role to serve as our main lens through which to view the world. It is now a dynamic extension of our physical identities rather than merely a passive screen for calling and texting. It is a digital key that allows us to access, observe, and manage our physical surroundings and products. However, as we increasingly rely on these devices during active, daily use, the boundary between digital accessible convenience and physical productivity becomes increasingly blurred. Many mobile applications, such as the Swedish app BankID [1] have evolved from optional tools into critical interfaces for interacting with the physical world. Making apps accessible is crucial as they become an indispensable part of everyday life. Although reputable guidelines, such as the Web Content Accessibility Guidelines (WCAG) 2.2 [2], offer a strong foundation for digital accessibility, they may not adequately handle the usage in dynamic environments. While WCAG provides essential technical standards for making content accessible to people with disabilities by focusing on principles like perceivability and operability, these guidelines largely deal with static situations [3][4].

Consequently, they may overlook Situationally Induced Impairments and Disabilities (SIIDs) since SIIDs are context-dependent. SIIDs are temporary conditions that mimic the effects of permanent impairments by limiting a user's ability to engage with a device due to environmental context rather than physical ability. Common examples include bright sunlight or glare simulating low vision, or walking while carrying objects to mimic motor impairments. These situational challenges are particularly common for users in dynamic environments, such as outdoors and cars [5], yet they remain distinct from the static scenarios typically addressed by traditional accessibility standards.

This thesis explores the relationship between mobile accessibility, SIIDs, and a Smart Product-Service System (S-PSS). The system controls physical equipment via a digital interface [6]. An S-PSS operates as a cohesive system made up of three interconnected layers. Digital platforms (the mobile interface or "hub" where data is processed), service components, and smart, connected products (the actual hardware with sensors). These elements, such as real-time safety alarms or maintenance tracking, provide the continuous value that characterizes the system [7]. The thesis specifically looks at the constraints of current accessibility standards when applied to active-use scenarios that occur in dynamic environments, such as managing physical equipment while moving or multitasking.

The study is made in collaboration with Thule, a Swedish company specializing in outdoor and transportation gear, including but not limited to roof racks, bike carriers, strollers, and luggage [8]. The research focuses specifically on the Thule mobile application, an S-PSS which contains products from Thule such as air filters, child safety seats and parking sensors. In these settings, a lack of accessibility is not only a usability issue but a potential safety risk. This configuration bridges the gap between mobile utility and hardware by enabling users to monitor and interact with their equipment through their mobile phones.

1.1 Research Question

Although mobile applications are used widely in on-the-go situations, existing accessibility guidelines may not always consider specific scenarios and instead focus on general use cases, such as static indoor environments. This research looks at the difference between general accessibility guidelines and the demands of the dynamic situations users may face in their daily lives. The following research question defines the basis of this thesis:

RQ1: What are the limitations of existing accessibility guidelines when applied in dynamic environments?

RQ2: How can context-specific accessibility recommendations be formulated and applied to address these limitations for mobile users?

This research question requires a two-phase approach to research. Initially, the study aims to identify the degree of insufficiency of the current guidelines. A questionnaire regarding mobile use in dynamic environments and an in-depth analysis of the existing guidelines will be employed to identify the gaps where these guidelines fail to account for variables such as strong ambient light, cognitive stress, and physical motion, which may cause SIIDs. The second phase of the approach focuses on formulating and applying potential solutions. Using the Research through Design (RtD) methodology, the creation of high-fidelity mobile prototypes will generate designerly knowledge [9]. This phase supports the translation of learnings from the questionnaire and in-depth analysis to concrete, context-specific recommendations. Through an iterative process, findings will be presented and the study aims to go beyond criticizing existing guidelines and propose functional context-specific recommendations that can bridge the gap and push human knowledge further.

1.2 Stakeholders

This section outlines the stakeholders of this thesis.

1.2.1 Chalmers University Of Technology

This research is based on the academic foundation of Chalmers University of Technology in Gothenburg. The thesis is being created, evaluated, and published inside the Department of Computer Science and Engineering (CSE), marking the end of the

Interaction Design and Technologies master's program. Supervisor Sara Ljungblad, a researcher with expertise in human-computer interaction, accessibility and design ethics, provides academic advice, and the Examiner Michael Heron will evaluate the report.

1.2.2 Thule Sweden AB

This thesis is conducted in collaboration with an external partner, Thule. With the motto "Bring Your Life", Thule is committed to helping people lead active lives by offering premium, eco-friendly solutions that make it simpler to move forward with the things that really matter [8]. A key component of the brand's aim as it transitions from conventional mechanical gear to an integrated ecosystem is its approach to app development. As a smart digital companion that improves the user's relationship with their physical equipment, the Thule application is not just a remote control. Thule's digital expansion demonstrates a dedication to smooth user experiences in ever-changing environments by including intelligent features in their hardware, such as real-time monitoring and safety notifications. In support of this digital evolution, this research is conducted in partnership with Thules R&D department to improve the accessibility of the mobile application and contribute to the brands expanding digital environment.

1.3 Aim of the Thesis

This thesis investigates the limitations of current accessibility standards, such as WCAG 2.2, when applied to mobile usage in dynamic environments. Employing a Research through Design (RtD) approach combined with the double diamond process, the study uses the iterative process of prototyping as a generative process. This allows for the exploration of environmental constraints that WCAG guidelines may overlook, ultimately producing a set of design recommendations for a context-specific scenario, and in this particular case it will be for the Thule application.

1.4 The Goal

The project has established the following concrete objectives in order to accomplish the stated aim:

1. **Identify Gaps in Current Guidelines:** Conduct an in-depth analysis of existing accessibility standards and perform a comparative study between these guidelines and the lived experiences of users in dynamic environments to pinpoint specific shortcomings of current standards.

2. **Heuristic Evaluation of Current Thule App:** Conduct an accessibility audit of the current interface using WCAG 2.2 as the primary framework. This baseline evaluation identifies fundamental design barriers, providing the necessary foundation to address more complex, context-specific challenges later in the study.

3. **Create Contextual Recommendations:** Develop a set of accessibility recommendations that are tailored for active-use scenarios, taking into account elements such as multitasking, intense glare, and stressful outdoor or in-car environments. Although guidelines serve as a basis, a compliance mindset frequently puts technical checklists ahead of the real user experience. Strict adherence to guidelines, according to Horton and Sloan [10] may ignore the practical context of use. In order for these recommendations to be genuinely effective, they must aim to promote informed empathy, moving the emphasis from simple compliance to a human-centered design process that takes into account changing user demands.

4. **Prototyping (The Artifact):** Utilize the RtD methodology to iteratively design a high-fidelity mobile prototype for the Thule application. This artifact will function as a way of knowledge generation, assisting in the development of the recommendations, while also serving as a practical application of the theory.

The prototyping phase and the development of recommendations are expected to be iterative processes. The insights gained through design will inform the trajectory of the research and be continuously integrated into the recommendations. While prototyping is used as a research tool throughout the study, a final high-fidelity prototype of the Thule application will be produced to showcase the practical application of the newly developed recommendations.

2

Background

This section provides an academic and theoretical context for the thesis. It introduces the Thule Application and continues by outlining the fundamental concepts of Universal Design and the Curb-cut effect, as well as WCAG. It then examines the concept of Situational Impairments as well as temporary and permanent ones, which is critical for understanding mobile usage in dynamic settings. It also evaluates dark mode as an interface strategy, contrasting its imagined benefits with empirical legibility findings. It also establishes a contrast between hedonic and utilitarian information systems to help frame user acceptability. Finally, it looks at the nuanced change of modern parenting, which is confounded by mobile phones' connection with digital utility and human presence.

2.1 The Thule App

Thule, long known for its mechanical expertise in load carriers, is progressively shifting toward a "connected mobility" framework. This transformation is particularly visible in the Thule mobile app and its integration with a specialized line of safety and lifestyle goods, such as modular car seat systems, innovative bicycle carriers, and environmental health accessories.

The Thule app acts as the hub for the company's growing Internet of Things (IoT) portfolio. Rather than serving as a simple digital handbook, the program enables real-time data processing and device telemetry. Thule is transitioning from a typical hardware firm to one focused on connected mobility. This shift is based on an S-PSS architecture, which connects physical equipment with digital intelligence [6]. The Thule App is the digital system of this ecosystem, processing data from integrated layers: smart hardware, a centralized mobile hub, and active service components. For example, the program monitors filter lifetime and interior air quality for purification systems, and new versions of their bike carriers include support for ParkSecure, a proximity-based security and monitoring function for high-end transportation equipment. It also has a new child safety seat to help parents safely transport their children.

The Thule product ecosystem is exemplified by different products, such as the Alfi and Maple/Elm modular child safety system, which replaces manual car seat installation with a digitally certified procedure [11]. Thule Alfi ISOFIX base, which uses SenseAffirm technology to give an unfailing digital interface for instantaneous

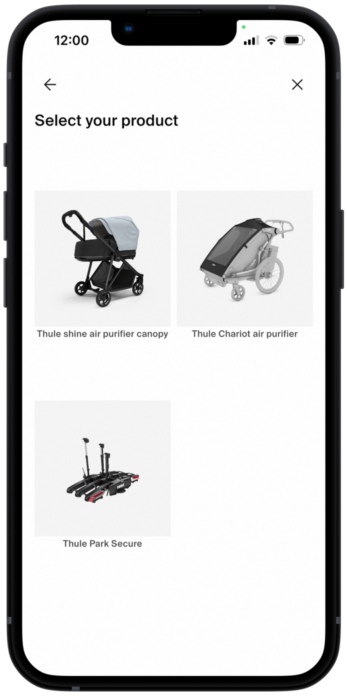

Figure 2.1: The page in the Thule application showing the available products

tactile and visual confirmation of structural soundness, is at the center of this. The technology guarantees ideal torque for ISOFIX connections by utilizing AcuTight mechanical accuracy, hence removing the possibility of human mistake during setup. While the inbuilt Impact Protection System is designed to disperse multi-directional kinetic energy after a collision, providing an additional layer of physical security, this foundation supports the Maple and Elm chairs via the EasyDock interface, enabling ergonomic rotation [11].

Through towbar-mounted bike carriers with ParkSecure technology, Thule has included Active Safety into its mobility solutions, going beyond pediatric safety [12]. This system addresses the logistical challenges of handling trucks carrying high-value, high-volume back cargo by utilizing rear-sensor arrays and app-based telemetry. The gear transmits its status directly to the user's mobile interface by offering security monitoring and real-time proximity help. This change signifies a change from passive equipment to an intelligent transport component that uses data-driven feedback loops to safeguard the vehicle and the cargo.

The Shine Air Purifier Canopy and the Chariot Air Purifier Cover represent another section of this integrated mobility framework. It is focused on pediatric environmental health. Up to 98 percent of airborne pollutants (depending on model), such as pathogens and PM2.5 particulate matter, are captured by these systems using medical-grade HEPA/EPA filtration. These rechargeable devices, which have a 16-hour battery life and are directly integrated with the Thule App, enable users to compare ambient urban data with the air quality of the child's microenvironment in real time. Standard strollers and trailers are transformed into controlled climate enclosures by this combination of airflow engineering and digital monitoring, protecting sensitive people in high-pollution urban areas [13].

As of 2026, the Thule app is clearly focused on items and services tailored to parents. This focus is reflected in the app's current integration of child safety seat systems and environmental air filtering monitoring for strollers, which turns it into a parenting tool.

Figure 2.2: The Thule products available in the application (2026)

2.2 Universal Design and The Curb-Cut Effect

The traditional "medical model" considers disability to be a personal characteristic and focuses on fixing the person through assistive technology [14]. To contrast this, UD believes that settings and systems should be created to be usable by the widest range of individuals feasible, without the requirement for adaptation or specialist design [14]. UD is built on seven core principles such as Equitable Use and Flexibility, to ensure products work for everyone, regardless of their personal skills or where they are. Ideally, design should work seamlessly whether you are indoors or outdoors. However, because outdoor spaces are complex and expensive to fix later, designers often settle for a "layered" approach. This unfortunately means that the needs of some users are put first, while others are treated as an afterthought. Thus, while UD remains the driving philosophy for this research, it is acknowledged as an ongoing process of improvement rather than a binary "achieved" state. Now let's look at a prime example of Universal Design.

The curb-cut effect is a phenomenon in which technology or design features designed to remove barriers for disabled persons result in positive externalities, or "spillovers", that eventually benefit non-disabled individuals as well [15]. The notion gets its name from actual ramps cut into curbs to assist wheelchair users, which were later discovered to help a variety of other pedestrians, including those pulling strollers, delivery carts, or baggage [16]. This effect is widely witnessed in the area of information technology, with developments such as the typewriter, closed captioning, and optical character recognition serving as excellent examples of assistive technologies that gained widespread adoption among the general population [15]. This aligns with the philosophy of this thesis, which also aims to make design features accessible to the broadest range of users. However, it is important to recognize that relying too much on the curb-cut effect risks sacrificing disabled (whether permanent, temporary or situational) people's special needs to the interests of the nondisabled majority. Reid [17] warns that focusing largely on these "positive externalities" may result in disability-led design being treated as a secondary concern in technical contexts.

2.3 The Web Content Accessibility Guidelines

The World Wide Web Consortium (W3C) created the Web Content Accessibility Guidelines (WCAG), which serve as the basic theoretical and practical framework for accessibility in the digital world. The most recent iteration, WCAG 2.2, includes guidelines to make material more accessible to individuals with disabilities, such as adjustments for blindness, low vision, and photosensitivity. The rules are organized around four key concepts, denoted by the abbreviation POUR [2]. So what defines it? First, content must be Perceivable, meaning that information and interface components are presented in a way that users can actually sense. It cannot be invisible to all of their faculties. Second, the interface must be Operable, ensuring that navigation and interactions are functional for the user and do not require actions they are unable to perform. Third, the system must be Understandable, requiring that both the information and the operation of the interface remain within the user's comprehension. Finally, the content must be Robust, allowing it to be interpreted reliably by a wide variety of user agents and assistive technologies, even as these technologies may continue to evolve over time.

While originally created for web content, WCAG principles are platform-independent and are increasingly being used in mobile applications. WCAG 2.2 is specifically designed to improve recommendations for users with low eyesight and disabilities on mobile devices. Key success requirements for dynamic mobile usage are minimum contrast and non-text contrast, which require precise brightness ratios between foreground and background elements to assure legibility. However, as discussed in the next section, academics argue that a strictly code-compliant strategy does not guarantee usability in dynamic, real-world scenarios, especially when surrounding circumstances impair the user in different ways.

2.4 Beyond WCAG: Alternative Models and Theories

Alternative theoretical and practical models have formed to question the interaction between human capacity, technology, and society systems. These frameworks and models expand beyond strict lists, shifting the analytical focus from individual limitations to systemic design, power dynamics, and dynamic interface adaptation.

2.4.1 The Social Model of Disability

The Social Model of Disability specifically opposes over-medicalized and individualistic explanations that portray disability as a personal shortcoming or tragedy [18]. This theory views disability as a kind of social oppression, cultural discourse, and environmental exclusion. A key component of this model is a rigorous distinction between "impairment", which is defined as a person's private physical, mental, or sensory limitations, and "disability", which is defined as the public structural disadvantage brought about by a modern social organization that gives people with impairments little to no consideration [18]. The social approach tries to reduce the stigma associated with personal fault. However, Shakespeare [18] also criticizes this approach, notably that its structural pursuit of a barrier-free utopia can sometimes overlook the complicated, lived experiences of physical or psychological distress associated with disabilities.

2.4.2 Critical Disability Studies

Critical Disability Studies approaches accessibility through the perspective of societal power relations rather than a physical condition. This domain questions the traditional charity model, which portrays impaired individuals as tragic, pitiful victims in need of repair [19]. Instead, it examines how disability interacts with other disadvantaged identities, such as race, gender, class, and sexuality to impact larger power relations. Finally, critical disability studies requires that disabled people be regarded as the major authorities on their own lived experiences, moving the goal of accessibility from basic institutional compliance to complete equality, accommodation, and thorough social reform [19].

2.4.3 Ability-Based Design Principles

These theoretical advances in computing and human-computer interaction are put into practice through frameworks such as Ability-Based Design. Throughout the design process, this method focuses accessible computing on a user's strengths rather than their impairments [20][21]. Rather of considering accessibility as a checklist that expects human users to adjust to rigid systems, often through stigmatizing assistive hardware add-ons. Ability-Based Design shifts the responsibility of adaptation fully onto the technology itself.

2.4.4 Inclusive Design Principles

Moving beyond binary compliance checklists, this methodology handles human variability in permanent, temporary, and situational contexts using seven key concepts. These principles were created by Swan et al.[22]. First, designers must provide a similar experience, ensuring that different interaction methods give equivalent quality, efficiency, and value, so that no user is left behind. Second, teams must analyze the scenario, improving interfaces to perform consistently in a variety of physical locations and external restrictions such as screen glare or low connectivity. Third, developers should employ similar structural, visual, and editorial patterns throughout the system to reduce cognitive burden and encourage user familiarity. Fourth, systems must provide control by allowing users to alter interface characteristics, such as zoom levels or automatic animations, to meet their specific demands. Fifth, interfaces must provide choice by allowing numerous unique interaction paths to fulfill a particular job. Sixth, design should prioritise content while simplifying interfaces to bring important information and critical functions to the forefront. Finally, rather than imposing additional structural obstacles, the system must offer value by incorporating natural platform features like voice input or geolocation to truly improve the user experience.

2.5 Situational, Temporary and Permanent Impairments

Situationally Induced Impairments and Disabilities (SIIDs) provide an important framework for this undertaking. Wobbrock [5] claims that the relationship between a user and a gadget is not static but varies depending on the context of use. Environmental circumstances can hinder a user's abilities just as severely as a physical disability [23]. For example, a parent pushing a stroller while using an app feels encumbered, which is a situational motor disability equivalent to having a lifelong physical disability [24].

Sarsenbayeva et al. [24] divide these impairments into environmental factors (light, noise, temperature) and user states (motion, encumbrance, and stress). For example, it has been demonstrated that cold ambient temperatures stiffen muscles and increase error rates [25], and that carrying bags greatly reduces touch accuracy [24]. In the context of outdoor applications, ambient illumination is of significant relevance. According to research, bright ambient light (glare) drastically reduces image quality on mobile devices, requiring users to invest more cognitive effort to comprehend information [26].

Tigwell et al. [27] specifically looked at "Situational Visual Impairments" (SVIs), revealing that these issues are diverse. Their findings indicate that SVIs are produced by a mix of ambient variables (glare), device factors (screen brightness), and human behaviors such as using sunglasses. Importantly, users frequently adopt physical coping methods to alleviate these limitations, such as tilting the device or obscuring the screen with their hand. This implies that contemporary mobile interfaces are frequently reactive rather than proactive, putting the burden of adaptation on the user.

While SIIDs emphasize the importance of environmental context, they are only one aspect of a broader spectrum of functional limitations [28]. A permanent disability refers to a persistent, long-term physiological or cognitive condition, such as a limb difference or chronic visual impairment. In contrast, a temporary disability is a short-term limitation caused by injury or sickness, such as a broken dominant arm or pupillary dilation after a medical exam. Although the duration and clinical cause of these states vary, the functional obstacles to mobile interaction (such as decreased accuracy or limited visual clarity) are similar.

Identifying the similarities between these categories ensures that accessibility is a universal rather than a specialised requirement, and that a user's capacity to interact with a device is influenced by both their biological condition and their current environment. For example, the interaction issues faced by a user with a permanent motor impairment may be functionally comparable to those of a user with a situational impairment in a dynamic environment [29]. Designing for the constraints of a dynamic environment serves as a stress test for an interface's usability. An interface that is reliable enough to work under high glare or when the user is moving can also make it easier to use for those with permanent or temporary disabilities.

Accessibility features must be non-stigmatizing in order to prevent user rejection. Sokoler and Svensson [30] advocate for embracing ambiguity, designing user interfaces that do not need users to disclose a vulnerability or disability. Accessibility thinking should adhere to this philosophy, which enables users to address needs, whether resulting from a chronic impairment, external stressors like glare, or personal preference, without disclosing their unique circumstances by organically incorporating relevant alternatives. More recent empirical research supports this, showing that when accessibility features are not seamlessly integrated, they can act as a beacon for stigma and lead users to actively reject or abandon the technology to avoid unwanted exposure [31].

2.6 Dark Mode: Legibility and Implementation

Dark mode (light text on a dark background) has become a popular user interface trend, frequently advertised as a solution for visual ergonomics and battery life on OLED screens [32]. Because of its widespread popularity and the contextual nature of user preferences, Sethi and Ziat [33] conducted research and concluded that dark mode is best when it is an optional user interface setting. Several years ago, tech giants like Apple and Google added dark mode capabilities to their mobile and desktop operating systems, promoting them as a way to save energy, increase productivity, and reduce visual fatigue [34].

According to studies [33] [32], people routinely switch between display polarities based on specific applications or ambient lighting, using dark mode mostly in low-light conditions to optimize visual comfort or simply because it is appealing and culturally relevant. As a result, offering dark mode as a customisable option enables designers to properly address the relationship between environmental light settings and subjective user enjoyment [33].

2.6.1 Visual Acuity vs. Comfort

Research on the benefits of dark mode has yielded varied findings. Erickson et al. [35] discovered that in the setting of optical see-through head-mounted displays, dark mode graphics greatly enhanced visual acuity and reduced eye fatigue when compared to light mode, especially in low-light conditions. Similarly, Paneru's [32] study of university students revealed a substantial subjective preference for dark mode, with 79% saying that it reduced eye strain. Traditional psychophysical research [36] [37], on the other hand, implies that positive polarity (black text on white backdrop) frequently results in lower readability thresholds due to negative polarity's halation effect, which causes bright letters on a dark background to blur. Dobres et al. [36] discovered that employing bold font weights might alleviate this disadvantage in dark mode, implying that inverting colors alone is insufficient; typographic changes are required to retain legibility.

2.6.2 Implementation Challenges

Despite its popularity, the use of dark mode is frequently inconsistent. Andrew et al. [38] point out that, while Android and iOS have system-wide dark mode settings, third-party application compatibility varies greatly. Ma et al. [39] studied over 6,000 Android apps and discovered that accessibility hurdles frequently persist in dark mode implementations. Their automated scanning identified numerous difficulties with text and icon contrast ratios when apps transition modes, showing that developers frequently interpret dark mode as a simple color swap rather than a distinct accessibility mode that must be validated against WCAG guidelines.

2.7 User Acceptance: Hedonic vs. Utilitarian Systems

Understanding how users perceive and accept accessibility features, such as dark mode, requires categorizing the application's nature. Van der Heijden [40] and Hu et al. [41] distinguished between utilitarian and hedonic information systems. Utilitarian systems are instrumental; their value originates from productivity and "productive use". Hedonic systems, on the other hand, give self-fulfilling value, with interactions motivated by delight and "prolonged use".

The Technology Acceptance Model (TAM) [42], which was first developed by Davis, asserts that two key beliefs, perceived usefulness and perceived ease of use, which determine a user's adoption of a system. Perceived usefulness, according to Davis, is the degree to which an individual believes that using a particular system would enhance his or her job performance whereas perceived ease of use is the degree to which an individual believes that using a particular system would be free of physical and mental effort. For utilitarian systems, perceived usefulness is the most important predictor of acceptance [40][41]. However, for hedonic systems, perceived enjoyment and simplicity of use become important factors. The Thule application may occupy a hybrid space: it is utilitarian (managing hardware such as outdoor gear) but operates in a hedonic setting (outdoor hobbies and leisure). As a result, the interface must meet pragmatic efficiency criteria while simultaneously appealing to hedonic aesthetics and visual comfort.

2.7.1 View on Mobile usage - Parents

The introduction of smartphones into the household and public spheres has radically transformed the terrain of modern parenting, resulting in a complicated interaction between digital usefulness and human presence. Johnson [43] finds that parents are ambivalent about the significance of mobile technology in daily parenting activities. While smartphones are useful tools for logistical coordination, social support, and safety, their presence also brings what researchers call "technoference", frequent disruptions in face-to-face encounters produced by electronic gadgets. Johnson's study demonstrates that parents are well aware of the potential for these technologies to reduce the quality of contact with their children, yet they continue to rely on them owing to the varied demands of modern living.

Johnson's [43] study explores the cognitive dissonance that parents suffer when they feel guilty or under societal pressure about their cellphone usage. Participants in the survey frequently expressed anxiety that their smartphone use would be regarded as a kind of neglect or distracted parenting, especially in public places.

2.8 Research Gap

Recent research indicates that WCAG 2.2 may have problems when applied to the variable nature of mobile usage [3]. Mobile devices are regularly used in dynamic environments, including outdoors, where factors such as sunlight glare have a significant impact on user experience. Budai [3] argues that key WCAG success criteria, especially those involving contrast, were established from readability considerations for desktop monitors seen from a set distance rather than the changeable conditions of mobile use. As a result, theres a doubt whether these guidelines are enough for the dynamic physical surroundings of mobile interaction. This highlights an important research gap; although research exists regarding WCAG [44] [45] [46], they don't focus on its effectiveness in dynamic environments. Further research is required to empirically evaluate whether adhering to WCAG 2.2 standards alone is enough to ensure accessibility under the variable environmental conditions associated with mobile use.

3

Methods

This chapter covers common methodology, including research approaches, data collection techniques, and design procedures. The goal is to establish a framework for the research. The process starts with an explanation of Research through Design (RtD), followed by a presentation of the design process and applicable methods.

3.1 Research Through Design

This study applies the RtD methodology to address the specific challenges of mobile accessibility in dynamic environments. Zimmerman et al. [47] define RtD as an approach in which design researchers generate knowledge by applying design practice to complex situations. This thesis directly addresses the potential shortcomings of static rules, such as WCAG 2.2, when faced with SIIDs, including split physical attention or glare. Unlike traditional scientific investigation, which aims to explain existing phenomena, RtD focuses on making objects meant to alter the current condition of the world into a desired state. This methodological choice aligns with the interests of Thule, whose brand identity is built on the pillars of safety, quality, ease of use, and design [8]. The selection of RtD is based on the concept that design is a generative discipline concerned with generating "what might be" rather than explaining "what is". According to Zimmerman et al. [47], RtD enables interaction design researchers to tackle complex problems by developing artifacts that aim to transform the current state of the world into a desired one. In the context of this thesis, the "preferred state" is a mobile interface that stays functional and secure in the face of dynamic conditions.

Following Gaver's [48] reasoning, this study does not aim to provide a generalized, falsifiable scientific theory, as such theories are frequently too abstract to inform specific design practice. Instead, the knowledge contribution of this thesis will be in the form of an annotated artifact. Gaver [48] contends that theory in RtD should be understood as an "annotation of realised design examples". This thesis aims to deliver actual, extensible information to other practitioners by developing context-specific recommendations and a functional prototype (the artifact) and thoroughly documenting the design decisions and trade-offs.

3.2 The Design Process - The Double Diamond

The Double Diamond model is a widely acknowledged representation of the design process, known for its ability to provide structure to creative problem-solving. The concept, which originated with the Design Council in the early 2000s, was not "invented" but rather codified from existing practices to make the design process visible and concrete [49]. The Double Diamond helps designers and non-designers overcome complicated challenges by visualizing the divergent and convergent stages of thinking, ensuring that solutions are based on real user demands rather than preconceptions. The double diamond design process combines divergent and convergent thinking into four phases: Discover, define, develop, and deliver. Methods appropriate for each phase are also defined.

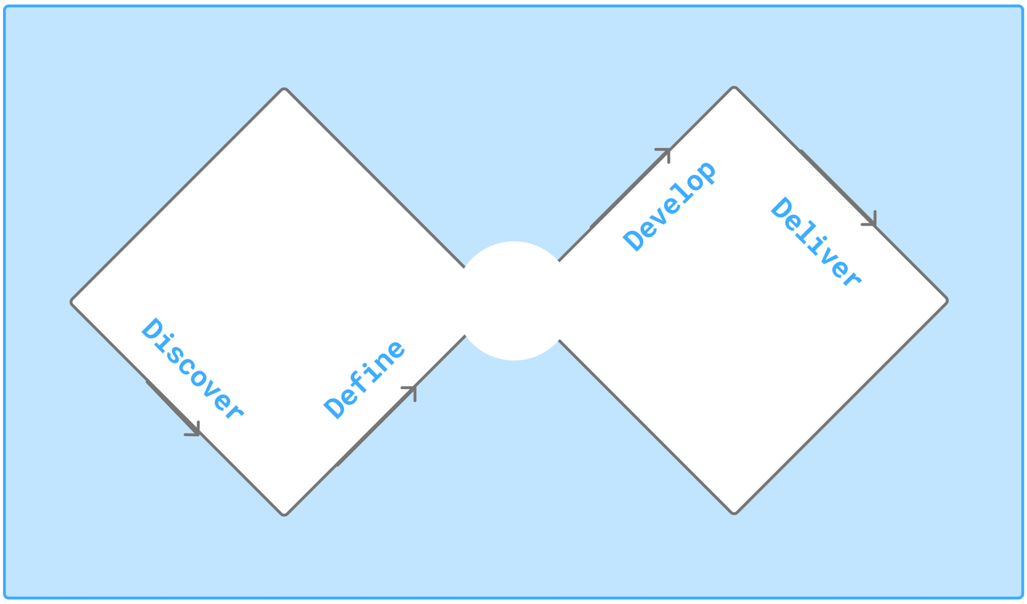

Figure 3.1: An illustration of the Double Diamond.

3.2.1 Discover

The main purpose of the Discover phase is to challenge the status quo and the original brief. Most efforts fail because teams rush to solutions based on preconceived problems. To avoid this shortcut, the Discover phase allows the design team to immerse themselves in the context of the challenge [49]. This may include conducting research to better understand the context, monitoring users, and identifying their true wants and goals. To achieve this immersion and build a solid basis, the project uses three separate investigation methods:

WCAG 2.2 Analysis (Grounded in Theory): The method begins with an assessment of existing standards (WCAG 2.2) and literature on SIIDs and related works, such as dark mode. This identifies the present state of the art as well as any potential gaps in current theories.

General Survey: To capture a diverse range of user experiences, a general survey is used to collect quantitative and qualitative data on mobile usage in dynamic environments. The primary goal is to assess how frequently people experience SIIDs and to identify the specific contextual factors that restrict their engagement with digital interfaces. By gathering information from a diverse user base, the study establishes the framework for identifying common "active-use" pain points, such as the difficulty of interacting with a phone while physically moving or the annoyance of poor sight in outdoor settings. This form serves as an important diagnostic tool, shifting the focus away from theoretical accessibility and onto the user's practical, lived experience.

Heuristic Evaluation of the Current Thule App: To offer a rigorous baseline, the study involves an accessibility audit of the current Thule mobile interface, with WCAG 2.2 serving as the main foundation. This technique is essential to discover and distinguish fundamental accessibility issues from those worsened by environmental stressors. Identifying potential static barriers early on ensures that the subsequent active-use criteria are based on a solid foundation of overall compliance.

Contextual Inquiry (Iterative Process): Contextual inquiry is a fundamental qualitative research approach in user experience design, used primarily to get deep insights into user behaviors, motives, and contextual limitations. According to Raven and Flanders [50], this field research approach differs from standard laboratory testing or structured interviews in that it embeds the researcher in the participant's actual setting. This technique is based on four guiding principles: context, relationship, interpretation, and emphasis. The notion of context requires that the inquiry take place in the natural setting, allowing researchers to witness activities as well as the subtle subtleties of the physical and social environments that impact task performance.

Targeted Survey (Iterative Process): Unlike the general survey, which promotes wide coverage, this survey takes a tailored, targeted approach. Lynn [51] defines targeted survey methods as a shift away from one-size-fits-all approaches and toward designs suited to the study's particular characteristics or requirements. This strategy guarantees that data gathering is tailored to the unique context of the research.

The targeted survey follows purposive sampling, a non-probability strategy used in quantitative research, ensuring that respondents possess the precise traits essential to answer the research questions [52]. Purposive sampling, as defined by Etikan et al. [53], involves selecting participants based on their characteristics and experiences. This method is especially useful when the study objectives demand specific technical or practical insights.

3.2.2 Define

Once data has been obtained, the process enters the Define phase. This stage is distinguished by convergent thinking, in which the lines of the original diamond narrow and intersect at a central point. The goal is to make sense of the data gathered during the discovery phase [49].

3.2.2.1 KJ Method

During this phase, all data collected from the theoretical analysis, the general survey on SIIDs, and the heuristic evaluation of the Thule app will be analyzed. It will be analyzed using the KJ method [54], synthesizing the data using a rigorous four-step method that aims to progress from individual observations to a comprehensive understanding of the user experience in dynamic contexts.

The first step in the procedure is label making, which involves condensing data from three main sources into distinct points. These will include the potential specific non-compliance issues found during the Thule mobile app audit, the qualitative comments from the general survey, and the technical guidelines found in the general WCAG 2.2 analysis.

The design team will then apply label grouping to these labels, interpreting each point's underlying meaning to find naturally occurring clusters. As the theme hierarchy is developed, lone wolves (individual observations that did not readily fit into a cluster) will be assessed as possible major concepts or be included in higher-level groupings. After most of the material is arranged, succinct "headers" will be made to encapsulate the main points of each group.

The links between these headings will be mapped using symbolic notation in the third stage, chart creation, which should reveal interdependencies, inconsistencies, and cause-and-effect patterns. Last but not least, the explanation process entails creating a narrative synopsis of these charts, sometimes presented as a "problem scenario," which influences the next design specifications [55].

An alternate method for finding recurrent themes in the qualitative data was thematic analysis. In order to create a conceptual model, thematic analysis usually entails a six-step coding procedure. Although it may examine qualitative inputs similarly to the KJ Method, it is frequently more appropriate for theoretical conceptualization when the main objective is to address a more general research topic [56]. However, for this project, the development of a working prototype and a user demand definition was inextricably related to the research objectives.

The focus is on going through the noise to achieve clarity. It takes discipline and order to organize this information and find patterns in user behavior. The findings from the audit and the survey provide a set of priorities for the subsequent phases, keeping the project grounded in the existing interface and real user data rather than starting from an abstract concept. The end result of this step is a reframed design challenge or a precise problem statement based on evidence rather than preconceptions.

3.2.3 Develop

With a precise problem definition in hand, the process moves to the second diamond, which begins with the Develop phase. This is another stage of divergent thinking, with the diagram widening again to represent a willingness to generate as many viable solutions as possible [49]. The Develop phase focuses on brainstorming, iteration, and experimentation.

3.2.3.1 Brainstorming

A collaborative ideation technique called brainstorming is intended to provide a wide range of original ideas in a group context [57]. The main goal is to promote divergent thinking, where participants are encouraged to think outside the box and put forth wild ideas. In contrast to solo ideation, brainstorming is based on the theory of associative synergy, in which a participant's thought stimulates another's, resulting in a broad spectrum of ideas that might not arise separately [58]. The approach adheres to four fundamental guidelines to optimize efficacy: emphasize quantity, refrain from criticism, accept novel concepts, and integrate or improve earlier recommendations.

Because brainstorming emphasizes group refining, it was chosen for this study. The participatory element of the approach was very helpful for this project since it made it possible to instantly include other viewpoints, guaranteeing that the solutions produced were not only numerous but also benefited from the group's collective knowledge.

3.2.3.2 Crazy 8s

A quick drawing activity called the Crazy 8's is intended to produce a variety of answers to a design challenge [59]. To begin, each team member folds a sheet of paper into eight sections. After that, participants are given eight minutes to swiftly draw one concept in each area, either finishing all of the sections or stopping when the timer goes off.

This phase uses the Creation as Inquiry approach. The core research activity is the iterative creation of context-specific accessibility rules and the new design of the Thule mobile application. As Gaver explains, the artifact serves as a "definite fact" for research. The designers employ the specialized knowledge learned in the first diamond to create concepts that meet the identified user needs. This method is fundamentally iterative; app designs and recommendations are regularly created, reviewed, and modified to ensure they successfully address the identified active-use pain areas.

3.2.3.3 Prototyping

One essential element of an iterative design approach is prototyping. These techniques enable early improvement, guaranteeing that the finished product offers a satisfying user experience while staying true to the original design goals. Low-fidelity conception gave way to a high-fidelity interactive model in this study's prototyping process. Prototyping is an essential tool for controlling a design's evolution, as Coleman and Goodwin [60] point out. By testing concepts in small chunks early on, researchers may determine whether they are feasible before devoting substantial time and resources to high-fidelity development.

A popular technique to create the foundation for different designs in the space of 2D user interface concepts is low-fidelity prototyping, which improves comprehension and advances design without requiring a large amount of time or cost[61].

Wireframes, which offer a basic visual overview of the suggested application, may subsequently be created from the sketches. Instead of focusing on polished design or visual content, the focus is on interaction flow and placement of structural pieces. These wireframes functioned as a filter for the application's structure and interaction. Before committing to high-fidelity details, the research team can concentrate solely on the navigation logic and the arrangement of structural pieces by eliminating visual aesthetics. [62].

High-fidelity prototypes, as opposed to wireframes, are interactive and replicate every feature of the finished product. They are crucial for finding problems with navigation, flow, and the fit between the user's mental model and the system's architecture, even if they demand additional time and commitment [61]. The Thule mobile application, which already makes use of an existing design system with predefined mobile UI components in Figma, is the subject of the project and foundation for further iteration and development.

The majority of the prototype process and the organization of the data synthesis inside the KJ method will be conducted using the design program Figma. Figma is a real-time, cloud-based collaboration application that facilitates all stages of the design process, from interactive prototyping to basic brainstorming. The team will be able to incorporate intricate interactions into design aspects because of its prototyping capability, which makes it possible to test the prototype on real mobile devices.

This study's design method is not linear. Rather, it goes through a cycle of development, testing, and improvement. Every iteration of the prototype is tested to determine what works and what doesn't. This guarantees that the final program is modified by user feedback and that any design issues are detected early.

3.2.3.4 Qualitative Usability Testing

Qualitative usability testing is the main method used to evaluate the prototypes. Instead of gathering data or assigning pass/fail scores, the objective is to see how users actually utilize the new design. The researchers can identify precisely where a subject hesitates, becomes confused, or struggles with a gesture by observing them as they navigate the particular user flows.

This approach is ideal for an iterative project since it emphasizes the why behind a user's actions. It offers the precise information required to implement useful modifications for the upcoming prototype.

3.2.3.5 Semi-Structured Interviews

Every test is followed by a semi-structured interview to gain a deeper understanding of the user's experience. This is an adaptable dialogue that is directed by a list of particular subjects, also known as an interview guide, but the participant is free to discuss what matters to them [63].

According to bell et al [64], this approach allows the respondent "a great deal of leeway" in their response. Even if a participant brings up an intriguing subject that wasn't on the first list, the researcher can still follow up on it. Because it enables the team to comprehend how the user "frames and understands" the interface, this flexibility is essential. The team may identify practical problems that could be overlooked in a more rigorous test, such as how a button feels when walking or how glare impacts the screen, by maintaining an informal and open dialogue. In order to keep the project focused on resolving real user issues, the insights obtained from these observations and interviews are then utilized to loop back and begin the subsequent design iteration.

3.2.3.6 RITE Method

To put this iterative approach into action, the study adopts the Rapid Iterative Test and Evaluation (RITE) method. As defined by Medlock et al. [65], the RITE technique differs from standard usability testing in that it emphasizes the early discovery and resolution of issues and insights that might move the design further.

If a problem is clearly identified and a solution can be implemented rapidly, the prototype is adjusted before the next round of iteration. This allows for fast verification that the design modification successfully fixes the challenge without creating additional obstacles or new pain points. The RITE method seeks to deliver "better products in less time" by allowing quick cycles of testing and refining [65]. When combined with semi-structured interviews, this process guarantees that the Thule app design is repeatedly refined while being anchored in the participants' deeper contextual understanding.

3.2.4 Deliver

Deliver is the final step that concludes the second diamond using convergent thinking. This step focuses on refining, selecting, and finishing the solution. It requires accuracy, perseverance, and thorough execution. Using the Creation as Inquiry method once more, the Deliver phase distills the many ideas generated in the Develop phase into the best possible solution. A Heuristic Comparison will be carried out in order to close the gap between design and academic proof. The finished prototype will be contrasted with the existing Thule application using the recently created context-specific recommendations. This analysis will highlight the specific areas in which the current application falls short of these new requirements and show how the updated artifact effectively fills those gaps. Because the artifact conveys the designer's views about valid approaches to the problem, this phase assures that the final product acts as a conclusion to the design process.

4

Process

Here is a clear roadmap of the study's execution. This chapter breaks down the methodological workflow. It is structured around the four pillars of the Double Diamond.

4.1 Discover

This subchapter showcases the initial research procedure to collect data, which includes a WCAG evaluation and a general user survey. It also contains the Thule application audit.

4.1.1 Analysis of WCAG 2.2

This subchapter establishes the foundation for comprehending web accessibility by examining the WCAG 2.2 framework and its application within current industry trends. The WCAG 2.2 guidelines serve as the primary recommendation from the W3C for making digital content accessible to individuals with visual, auditory, physical, speech, and cognitive impairments. Published in 2023, WCAG 2.2 was formally accepted as an International Organization for Standardization (ISO) standard in 2025, further enhancing its reputation as the global benchmark for digital accessibility.

Although WCAG was initially developed in 2008 for desktop web usage, technological innovation has since shifted the focus toward a device-agnostic approach. The guidelines are now designed to be applicable to a diverse range of hardware, including mobile phones, kiosks, and computers. To support this transition, the Guidance on Applying WCAG 2.2 to Mobile Applications (WCAG2Mobile) [66] assists designers and developers in implementing these standards across mobile and web applications.

4.1.1.1 Principle 1: Perceivable

The first principle states that information and user interface components must be presented to users in ways that they can understand. **Guideline 1.1** mandates text alternatives for non-text content. In mobile applications, this means that controls and inputs must have programmatically associated names that describe their function, and while CAPTCHAs are uncommon in native apps, when utilized, they must give accessible alternatives. **Guideline 1.2** addresses time-based media by requiring captions and audio descriptions for pre-recorded video and audio. The mobile recommendation states that secondary audio tracks are frequently used to give these audio descriptions in native contexts.

Guideline 1.3: Adaptable, is especially relevant for mobile use. **Success Criterion (SC) 1.3.4: Orientation,** states that content must not limit its view to a particular orientation, such as portrait or landscape, unless it is required for the function, as in a piano application. The mobile recommendation underlines that apps should support all orientations, including reversed portrait and landscape, in order to enable users with fixed mounts on wheelchairs or strollers. Furthermore, **SC 1.3.5: Identify Input Purpose,** demands that input fields containing user data be programmatically determined in order to support autocomplete. In mobile scenarios, this is dependent on the underlying platform's ability to recognize typical input types, such as e-mail or phone fields.

Guideline 1.4: Distinguishable, aims to make content easy to perceive and hear. The contrast standards **(SC 1.4.3 and 1.4.11)** specify a minimum ratio of 4.5:1 for text and 3:1 for user interface components against their background. The mobile guidance emphasizes that while platform settings might change visual styles, app developers must ensure that their defined colors fit these ratios to serve users in a variety of lighting conditions. **SC 1.4.10: Reflow,** specifies that material can be magnified up to 400% zoom without requiring two-dimensional scrolling. For native mobile apps, this is read as the interface's ability to reflow content when the user changes the operating system's display size or font scaling settings, ensuring functionality is maintained without data loss. Furthermore, **SC 1.4.12: Text Spacing,** ensures that information is legible when users override text styling properties; however, this is only applicable if the mobile OS permits users to change such values globally.

4.1.1.2 Principle 2: Operable

The Operable concept assures that user interface components and navigation are functional. **Guideline 2.1** requires all functionality to be keyboard accessible. The mobile advice explains that "keyboard" does not necessarily refer to a physical keyboard, but rather to any interface that allows keystroke input, such as external keyboards attached to mobile devices or assistive technology that simulates keystrokes. As a result, mobile apps must not trap keyboard focus **(SC 2.1.2)** and should offer alternate input methods other than touch.

Guideline 2.4: Navigable, specifies page titles, focus order, and focus visibility. In the mobile context, **SC 2.4.2** requires that each screen or view include a title that describes its purpose to facilitate orientation. **SC 2.4.11: Focus Not Obscured (Minimum),** a new addition to WCAG 2.2, is crucial for small screens since it requires that the item receiving focus not be completely obscured by author-created material, such as sticky headers or floating action buttons.

Because mobile interfaces rely heavily on touch interaction, **Guideline 2.5: Input Modalities,** is substantially developed. **SC 2.5.1: Pointer Gestures,** requires that functionality accessed by multipoint gestures such as pinch-to-zoom, offer a single-pointer alternative, such as a +/- button, unless the gesture is required. **SC 2.5.2: Pointer Cancellation,** specifies that functions respond to the "up-event" rather than the "down-event", allowing users to slide their finger off a target to cancel an accidental push. **SC 2.5.4: Motion Actuation,** addresses sensors and states that functionality triggered by device motion such as shaking or tilting, must be disabled to avoid unintentional activation in dynamic contexts.

New to WCAG 2.2 are criteria that focus on touch accuracy. **SC 2.5.7: Dragging Movements,** necessitates a simple pointer replacement for any action that needs dragging, such as sliders or reordering lists. **SC 2.5.8: Target Size (Minimum)** requires a target size of at least 24 by 24 CSS pixels. The mobile recommendation recommends that for platforms that do not use CSS pixels, targets be evaluated using the platform's corresponding density-independent measurement units to verify they are large enough to be accurately activated.

4.1.1.3 Principle 3: Understandable

The Understandable principle aims to make information and actions predictable. **Guideline 3.1** requires programmatic determination of the human language displayed on a screen. Mobile apps often achieve this by adhering to the operating system's "locale/language" option. **Guideline 3.2: Predictable,** ensures that user interface components perform consistently. **SC 3.2.1** and **3.2.2** state that obtaining focus or modifying settings should not automatically trigger a change of context, such as going to a different screen, without the user's permission. The new **SC 3.2.6: Consistent Help,** demands that if help mechanisms such as contact information or chatbots are available, they display in the same relative order across multiple screens, referring to their position in the view's serialization.

Guideline 3.3: Input Assistance, is intended to assist users in avoiding and correcting errors. **SC 3.3.4: Error Prevention (Legal, Financial, Data),** is critical for high-stakes interactions, requiring means to reverse, review, or confirm submissions that alter data or result in legal commitments. The new **SC 3.3.7: Redundant Entry,** requires that information previously provided by the user to be auto-populated or available for selection in the following phases to reduce cognitive load. Furthermore, **SC 3.3.8: Accessible Authentication (Minimum),** prohibits using cognitive function tests such as memorizing passwords or solving puzzles for authentication unless biometric login, password managers, or copy-paste capability are available. The mobile guidance states that passwords required to unlock the device itself (OS level) are outside the scope of the application developer.

4.1.1.4 Principle 4: Robust

The Robust principle ensures that material can be understood by a diverse range of user agents, including assistive devices. Notably, **SC 4.1.1: Parsing,** has been eliminated and declared outdated in WCAG 2.2 since modern browsers and assistive technologies can successfully manage HTML parsing issues. The primary focus remains on **SC 4.1.2: Name, Role, and Value,** which mandates that all user interface components have programmatically determined names and roles. In mobile development, this is best handled by employing the accessibility services and APIs supplied by the platform (for example, Android Accessibility Suite or iOS Accessibility/VoiceOver), which enable interoperability with screen readers. Finally, **SC 4.1.3: Status Messages,** requires that updates to content such as search results appearing be announced to assistive technology without moving the user's focus, typically implemented via "live region" equivalents in mobile accessibility APIs.

4.1.2 General Survey

The Discover phase of the design process began with a general questionnaire that aimed to discover the existing pain points that mobile users encounter in dynamic environments. The questionnaire was sent to a demographic predominantly composed of middle-aged office professionals and Master's level students, and received 65 responses. To ensure a thorough examination of these lived experiences, the survey used a variety of data types: nominal values were used to categorize dynamic environments (e.g., commuting vs. walking); ordinal values, such as 5-point Likert scales, were used to measure the frequency of these pain points and user sentiment; and interval-like data was captured using a 1-5 numerical scale to quantify the perceived difficulty of mobile use in motion relative to static environments. This approach enables a detailed analysis of how environmental stresses affect interaction quality across a varied range of active-use circumstances.

Following Bell et al.'s suggestions [64], a digital self-completion survey was chosen over structured interviews to avoid interviewer variability and regional constraints. Importantly, it minimized the social desirability effect while the survey addressed cognitive overload and physical limitations, the impersonal digital format created a safe space for honest, unjudged reporting.

To maximize validity, the questionnaire was designed using strict rules. To eliminate unclear phrases, subjective frequencies such as "often" were substituted by numerical anchors (for example, "Occasionally (2-4 times)"). To avoid double-barreled questions, variables were separated into discrete matrices, such as "difficulty seeing the screen" and "difficulty tapping accurately". Furthermore, the poll employed neutral Likert-style statements rather than leading questions to ensure that respondents were not pushed toward leading answers.

According to Bell et all.'s criteria [64], the survey transitioned intuitively from broad context (commuting/walking) to specific interaction issues. To prevent respondent fatigue, the design used standardized closed-ended questions with a consistent frequency scale. Complex filter questions were avoided to keep the interface simple and maintain responder engagement throughout.

One significant advantage of this closed-question structure is that responses were pre-coded, which greatly aided the quantitative analysis. By asking respondents to designate themselves to specified categories, numerical codes were automatically issued. This removed incorrect post-coding, allowing frequency tables to be generated immediately after importing data.

While self-completion may result in missing data due to a lack of supervision, this was reduced by a concise, simple form. To compensate for the absence of probing, a single optional open-ended "critical incident" question was included. This enabled respondents to add important contextual details, effectively bridging the gap left by the absence of an interviewer.

The dataset was carefully inspected to address missing data. As stated by Bell et al. [64], missing data might occur when respondents pick "I don't know" or neglect to respond. As seen in Figure 4.1, the 8 instances of "I don't know" about developer accessibility were assigned a discrete missing value code (e.g., 0 or 99) to avoid unnecessarily distorting the statistical analysis of legitimate responses. Finally, the optional open-ended question about critical incidents was subjected to post-coding, in which rich textual descriptions (e.g., "raining so the screen was hard to work with", "cold, my fingers were stiff", "bright sunlight caused screen glare") were systematically classified into thematic variables.

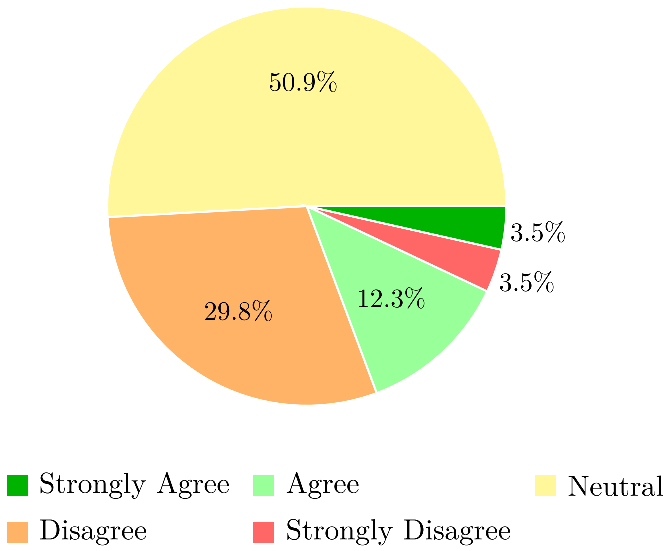

Figure 4.1: To what extent do you agree with the statement: "Mobile app developers sufficiently consider accessibility for users in dynamic environments." ($N = 57$).

Univariate analysis is the study of one variable at a time. Frequency tables and percentages were created to better understand mobile consumers' key pain points in dynamic contexts. When asked if mobile app developers take accessibility for users in dynamic situations seriously, the responses suggested a mostly distrustful and unenthusiastic user base.

Furthermore, when isolating the category factors for physical interactions, the clear majority of respondents chose "typing/text input" and "tapping small buttons" as the most difficult physical acts to execute while in motion.

Central tendency measurements were used to determine a typical value for the distribution of scores for the "Overall difficulty of using mobile apps in dynamic environments in comparison to static environments" (measured on a 1 to 5 scale). Because this is an ordinal variable, where categories can be rank-ordered but the distances between them are not absolutely equal, the median and mode are excellent measurements, however the arithmetic mean is also frequently used to calculate the exact average. These data show that the sample's central tendency is solidly at a neutral level, with a Mean: 3.03, Median: 3.0 and Mode: 3.0.

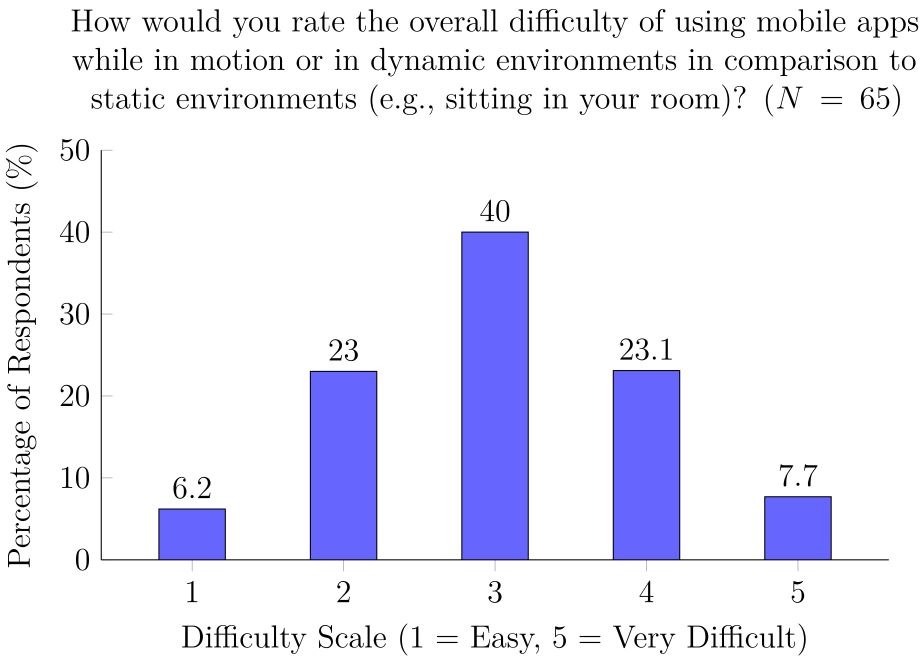

Figure 4.2: Overall Difficulty Rating: Motion vs. Static Use ($N = 65$).

Bivariate analysis explores the relationship between two variables at the same time to see if one's variation correlates with that of the other. A contingency table was used to cross-tabulate "Frequency of Use in Dynamic Environments" (the independent variable) with "Overall Difficulty" (the dependent variable).

The study reveals a striking pattern of association: respondents who reported using their phones "frequently (10+ times)" per week in dynamic surroundings (22 respondents) indicated moderate to high overall difficulty scores, with several rating the difficulty as 4 or 5. As the methodological literature advises [64], bivariate analysis establishes connections rather than causality. However, this association strongly indicates that repeated exposure and daily practice may not reduce the physical and cognitive friction associated with utilizing mobile apps in dynamic contexts.

Furthermore, our bivariate analysis demonstrates that this friction is not a "learning curve" issue; frequent "power users" face the same challenges as occasional users. As seen in Table 4.1 and Figure 4.3, the data clearly identifies various interaction obstacles, such as entering text, tapping small targets, and coping with glare.

4.1.3 Thule Mobile App and WCAG2Mobile

This chapter presents a comprehensive accessibility audit of the Thule mobile application (Figure 4.4), which served as a continuation of the discovery phase. Using the WCAG2Mobile [66] framework, which translates the WCAG 2.2 [2] guidelines for mobile environments. By examining high-fidelity Figma prototypes alongside the

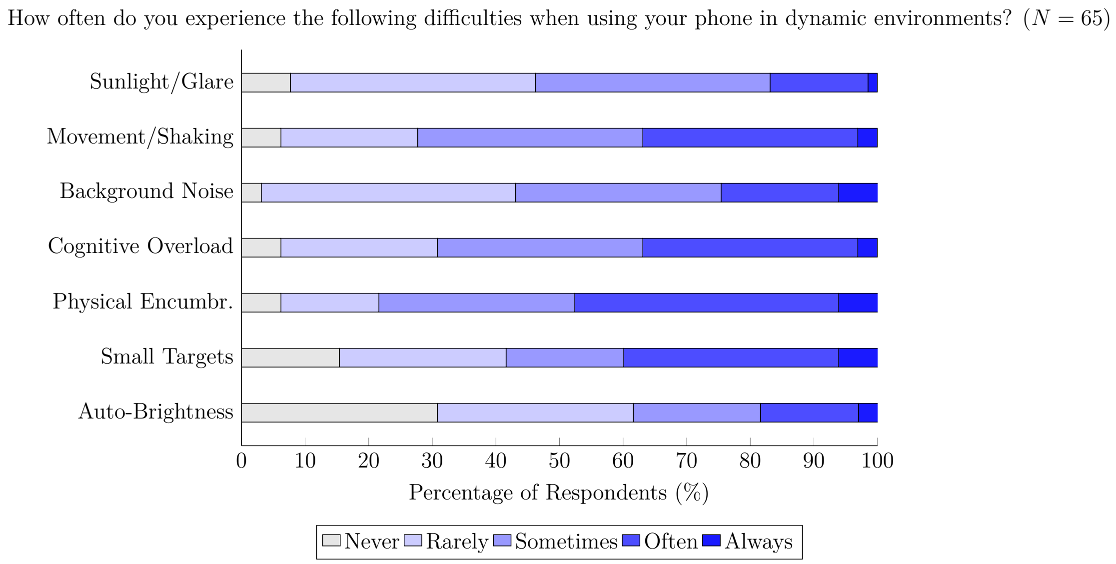

Figure 4.3: Frequency distribution of reported environmental and physical challenges encountered by respondents ($N = 65$).

Table 4.1: Frequency of Most Commonly Reported Interaction Challenges ($N = 65$)

Interaction Challenge	**Count (n)**	**% of Respondents**
Typing/Text Input	55	84.6%
Reading long articles/messages	38	58.5%
Tapping small buttons	31	47.7%
Holding the device securely	20	30.8%
Viewing the screen due to glare	15	22.7%

Note: Percentages do not sum to 100% as participants were permitted to select multiple challenges.

live application, this audit identifies critical functional barriers and existing design strengths to establish a baseline for the product's current accessibility health.

4.1.3.1 Compliance and Non-compliance

Using the WCAG2Mobile standards, we performed an accessibility audit of the current Thule mobile application during the discovery phase. Our approach centered on the visual layout, navigation logic, and anticipated interaction behavior, evaluating both the default state and the experience using the iOS screen reader, VoiceOver [67]. Because the audit relied on high-fidelity Figma prototypes rather than a compiled codebase, we applied these industry-standard criteria early in the design phase to identify potential barriers to entry before formulating context-specific recommendations.

This analysis serves two primary objectives: first, to establish an objective baseline of the application's accessibility status in order to assess how well it meets a range of user needs. Second, this procedure facilitates a deeper technical comprehension of

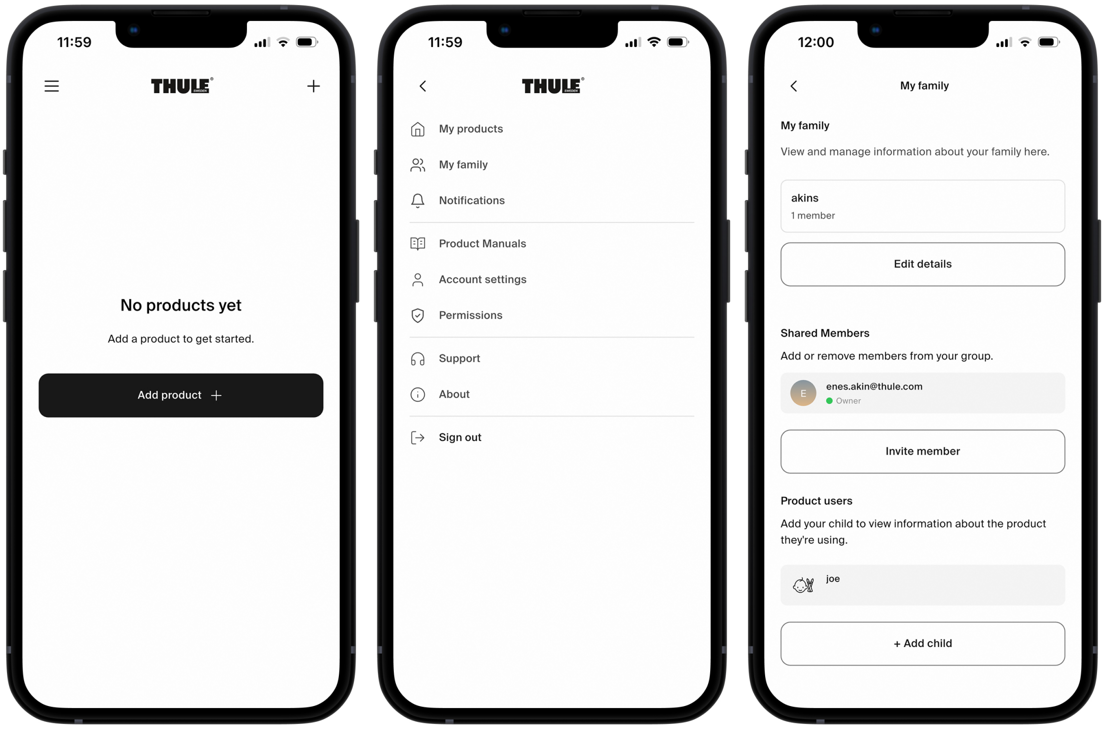

Figure 4.4: Three different screens from the Thule application

the WCAG framework through hands-on practice. By applying these standards to a commercial product, the intrinsic strengths and limitations of the current guidelines become more apparent. This viewpoint is essential because the ultimate objective of this thesis is to expand upon existing standards by developing more comprehensive, dynamic rules for mobile applications.

Areas of Non-Compliance

While the application demonstrates a robust foundation in several categories, it fails to meet specific success criteria regarding complex gestures and programmatic labeling.

Success Criterion 2.5.1: Pointer Gestures (Level A)

This criterion states that *all functionality that uses multipoint or path-based gestures for operation can be operated with a single pointer without a path-based gesture, unless a multipoint or path-based gesture is essential.* The application fails in the product handbook section, where users must "pinch-to-zoom" to navigate product manuals provided as PDF files. The interface lacks "+" or "-" buttons or alternative on-screen elements capable of executing this function via a single press. This is significant since critical safety and configuration information becomes inaccessible to users with motor impairments who cannot coordinate multi-finger motions.

However, it is important to note that these product manuals are not restricted to the digital application; they are also included with the products as a physical booklet.

Success Criterion 4.1.2: Name, Role, Value (Level AA)

This criterion states that *for all user interface components, the name and role can be programmatically determined; states, properties, and values that can be set by the user can be programmatically set; and notification of changes to these items is available to user agents, including assistive technologies.* The audit revealed that navigation items, specifically the settings gear and the "burger" menu icons, are identified by screen readers as "image" rather than "button". Consequently, a user relying on assistive technology may not realize these components are interactive. For users with visual impairments to have an equal experience, each icon must possess a functional role and a descriptive text label.

Success Criterion 2.1.1: Keyboard (Level A)

This criterion states that *all functionality of the content is operable through a keyboard interface... except where the underlying function requires input that depends on the path of the user's movement.* In a mobile context, this translates to ensuring that all interactive elements are reachable using assistive technologies like iOS VoiceOver [67] or Android TalkBack [68], which navigate via a focus-based system.

The application presents a critical failure during the "Security Information/Terms and Conditions" step. The "I have read and understood" button is programmatically disabled until the user scrolls to the bottom of the text. However, the standard swipe-to-navigate action fails to trigger the "scroll" event required by the app's logic to enable the button. As a result, the button remains "dimmed" and unselectable even after the user has heard the complete text. This creates a total functional blocker that prevents users reliant on screen readers from progressing through the onboarding process.

Areas of Compliance

Success Criterion 1.4.3: Contrast (Minimum) (Level AA)

This criterion ensures that *there is enough contrast between text and its background so that it can be read by people with moderately low vision.* We confirmed that the vast majority of screens satisfy both AA and AAA requirements using the Stark plugin [69] for Figma [70]. Where text appears "faded" (such as for unavailable products), it serves as a purposeful design decision to convey state, while the main functional text remains highly readable. This high level of contrast is essential for mobile applications used outdoors or in high-glare settings.

Success Criterion 3.3.1: Error Identification (Level A)

The criterion states that *when an error is detected, the item that is in error must be identified and the error described to the user in text.* This is effectively managed within the login and account settings screens. For instance, if a password confirmation fails to match, the app provides a clear text description of the discrepancy alongside a red border for visual emphasis. This reduces the cognitive burden required to troubleshoot form entries, making the application more "forgiving" for all users.

Success Criterion 2.5.8: Target Size (Minimum) (Level AA)

The criterion states that *to ensure that users can easily activate functions, touch targets should be large enough to be pressed accurately.* The application satisfies this requirement by ensuring that even small icons, such as the "back" arrow, are housed within a container measuring at least 24 by 24 pixels. The use of expanded "invisible hitboxes" benefits users with poor fine motor skills or those operating the device while in motion.

4.1.3.2 Insights from the Analysis

The results of this indicate that the Thule application possesses a solid baseline for general accessibility, particularly regarding visual clarity and error handling. However, the overall usability is hindered by technical gaps in how interactive features are programmatically defined and how complex content is navigated.

The key takeaway from this audit is that while WCAG provides a vital technical foundation, it often focuses on "under-the-hood" compliance, specifically how code is parsed by assistive tools. There is a noticeable lack of guidance regarding the nuances of the visual and cognitive experience in a mobile context. Factors such as visual hierarchy, button placement, and information flow are just as critical as screen reader support when an application is used in dynamic environments. A page may pass a technical audit yet remain cognitively overwhelming if the guidelines do not account for the clarity required in high-stimulus contexts.

The W3C acknowledges these shortcomings, noting that WCAG does not address every user need [2]. It is difficult to establish "one-size-fits-all" visual rules without infringing on artistic freedom or stifling design innovation. However, this is precisely where context-specific recommendations must be implemented to augment the foundations of WCAG, ensuring a superior user experience across the entire user base.

4.2 Define

Following the considerable data collecting in the Discover phase, the emphasis switched to transforming these insights into meaningful design specifications. To go from raw data to organized problem formulation, the KJ Method was used to methodically organize the unstructured information acquired from the WCAG analysis, general survey, and Thule app assessment.

4.2.1 KJ Method

The KJ Method was chosen due to its capacity to prioritize user-centered data and reveal hidden patterns in complex, multi-source research. Unlike purely theoretical frameworks, this method is founded on evidence-based "atoms" of information, making it a suitable bridge between identifying accessibility hurdles and developing practical design requirements. The implementation of the KJ Method followed a four-step method.

4.2.1.1 Label Making and Label Grouping

The process began with condensing the raw data into distinct labels. These labels revealed things such as technical non-compliance issues of the Thule app, specific survey results, and user pain points. These were then divided into four naturally occurring clusters: Physical Precision and Motor Control, Sensory and Environmental Interference, Programmatic Logic and Assistive Tech, and User Sentiment and Cognitive Load. As seen in Figure 4.5, the affinity diagram was created with these labels and clusters. During this stage, a "lone wolf" observation (the absence of a dark mode version in the Thule app) emerged as a significant outlier that did not fully fit into the clusters but remained an important aspect in the environmental adaptability of the app.

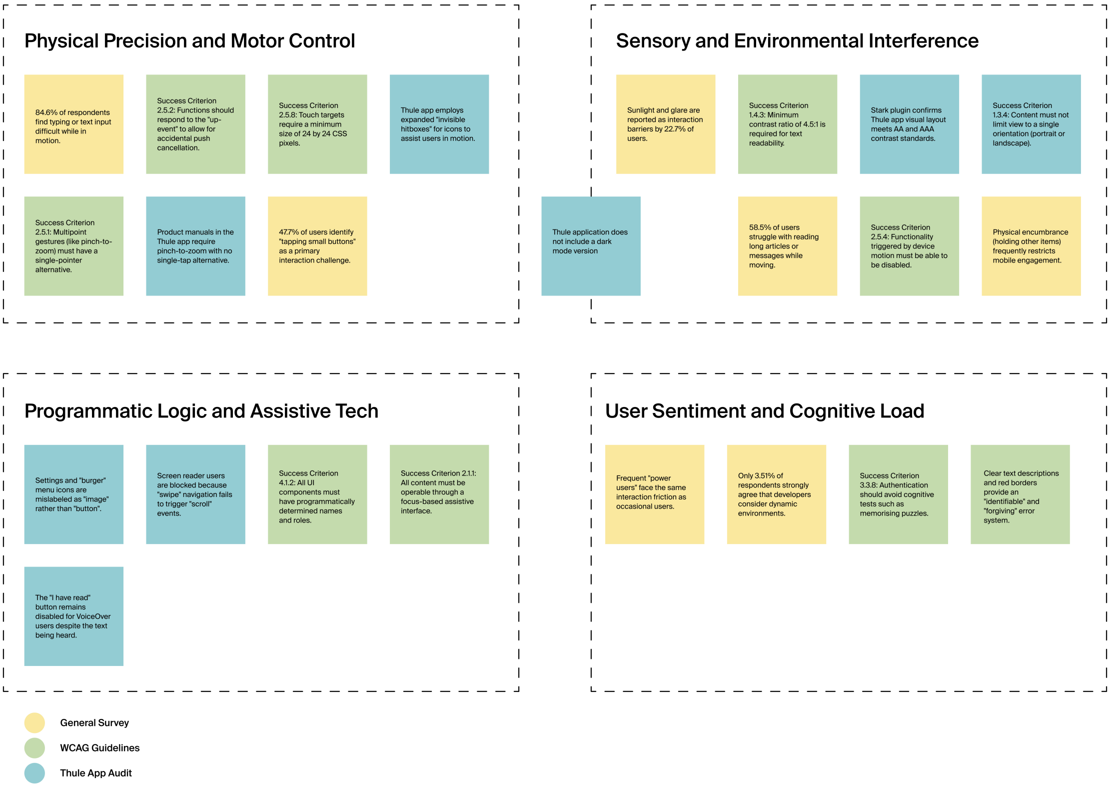

Figure 4.5: Affinity Diagram illustrating the clustering of observations from the WCAG 2.2 analysis, Thule app evaluation, and the survey.

4.2.1.2 Chart Creation (Relational Mapping)

Once the data had been sorted into thematic clusters, the process moved from categorization to active analysis by creating a Relational Map, as illustrated in Figure 4.6. While the previous step focused on grouping similar observations, relational mapping seeks to find the underlying "logic of friction" by determining how these diverse data points interact, conflict, or compound one another. This step is crucial because accessibility issues in dynamic environments are rarely isolated. Instead, they are caused by environmental stressors and technical restrictions that combine to form a situational impairment.

The mapping process entailed a thorough review of the labels within each cluster to identify their interdependence. By physically connecting WCAG guidelines, user data, and specific application failures, the design team moved from a static list of problems to a cause-and-effect model. This holistic approach ensures that the final design specifications address the underlying causes of user frustration rather than simply fixing the symptoms. To ensure methodological rigour, the following symbols were employed to define these relationships:

- Conflict (↔): A direct tension or contradiction between two nodes where one factor opposes the successful execution of another.
- Causation (→): A direct influence or causation, where the presence of one factor leads to the necessity of another.
- Correlation (- - →): An indirect relationship that suggests a link without establishing a direct causation.

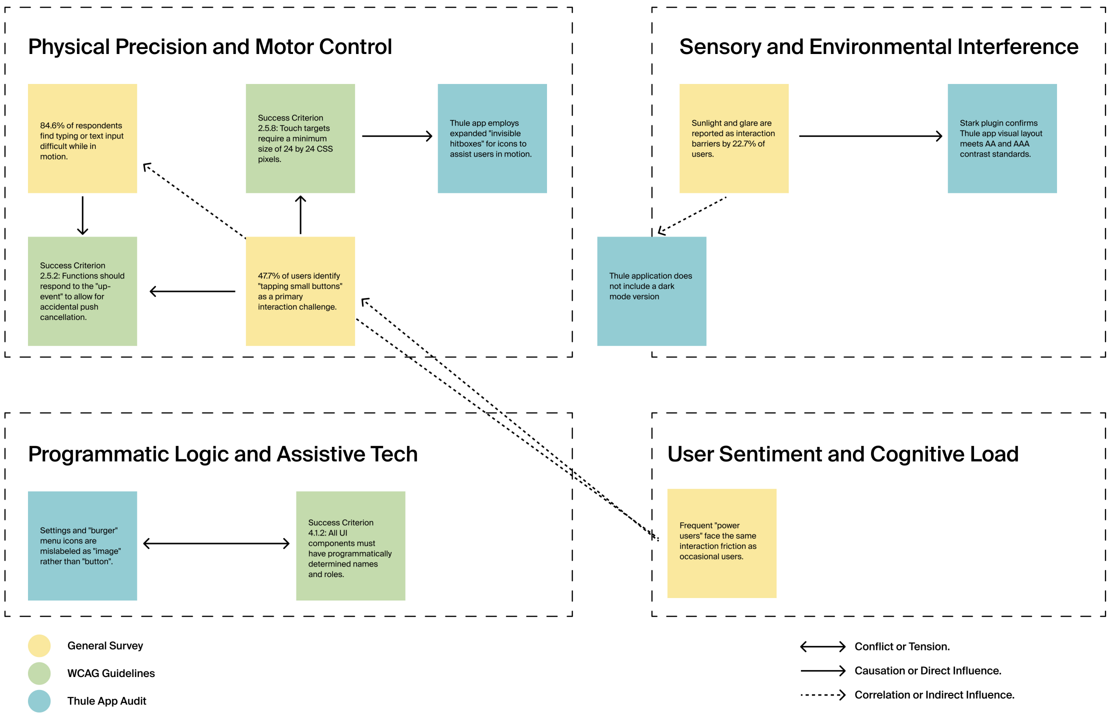

Figure 4.6: Relational Map identifying the interdependencies and conflicts between some of the observations.

4.2.1.3 The Explanation Process: Narrative Synthesis

The Explanation Process is the final phase in the KJ Method, which translates the Relational Map's abstract logic into a narrative synthesis. For this project, the explanation focuses on the compounding nature of issues arising in dynamic environments regarding the full Thule interface rather than a single isolated problem and a user story. The narrative reveals that the existing Thule application design may fail in dynamic environments. The following synthesis demonstrates how the individual friction points identified in the relational map (Figure 4.6) combine to produce a systemic failure:

Imagine a parent standing by their vehicle at night, using the Thule application to ensure that the baby seat is properly installed in their car before placing the child on the seat. The user is physically restricted, holding their child in one arm and attempting to operate the mobile app with their other hand. Because their attention is divided and their physical stability is affected by the child's movements, their fine motor precision is reduced. However, the program relies on industry standard 24px targets, which are difficult to activate accurately in this high-load situation. The sensory environment further increases the cognitive effort required for the task. It's dark, and because the Thule app doesn't have a dark mode, the bright white light on the screen creates substantial visual discomfort and brief night blindness. In this situation, the user must redirect mental attention away from the child and the seat in order to focus on simple screen navigation. This case highlights that, even if an app is technically "compliant", a lack of situational resilience can lead to user frustration and a breakdown in a dynamic environment.

As a result, the "problem" described is a failure to adapt to changing circumstances. This synthesis supports a comprehensive redesign strategy that strives to refresh the application's visual hierarchy and input modalities to ensure it remains functional in the face of active-use, multitasking circumstances in dynamic environments.

4.3 Develop

This section outlines the process of creating the different iterations of a prototype, from ideation to execution.

4.3.1 Ideation

Having developed a theoretical foundation via research and several analyses, the research phase now enters the ideation stage as a part of the development phase, which includes several stages of refining novel design concepts.

4.3.1.1 Brainstorming

The brainstorming session that followed was based on the information gathered during the KJ Method synthesis, which integrated WCAG 2.2 analysis, the Thule app evaluation, and the general survey. The process started with a collaborative session that acted as a divergent thinking stage and produced a large number of solutions to the challenges found during the discovery phase. The team concentrated on associative synergy by working as a study pair, where the recommendations of valuing quantity and accepting "wild" ideas allowed one participant's concept to inspire another. In order to record concepts quickly, this session was first performed in an analog form, utilizing sticky notes.

Figure 4.7: This complete digital set of ideas was the outcome of the brainstorming session.

4.3.1.2 Crazy 8's

Following the brainstorming session, we conducted a two distinct Crazy 8's sessions on the same day. The goal with these two sessions was to quickly sketch and visualize the abstract ideas explored and discussed in the brainstorming session and also to use quick sketching as a means of ideation.

Session 1: Visualizing Brainstorming Concepts

The first session served as a bridge between abstract ideas and visual execution. We chose six high-potential concepts from the previous brainstorming session that were best suited to sketching. Both researchers separately depicted these same six concepts, yielding a comparative set of 12 sketches. This enabled the us to assess several visual interpretations of the same functional requirements (such as placing important components in the thumb-zone, improved user manual viewer and the "heavy hand" filter) in the context of the existing interface.

In order to maintain structural and visual consistency, this session followed the application's predetermined design framework. Instead of completely reorganizing page layouts or essential elements, the current interface was used as a starting point for improvements. Figure 4.8 displays the sketches created during this stage. In order to allow a collective critique, researchers shared their outputs after the sketching phase. The quick nature of the Crazy 8's technique naturally results in low-fidelity representations due to strict time restrictions, so the discussion was crucial for aligning conceptual interpretations.

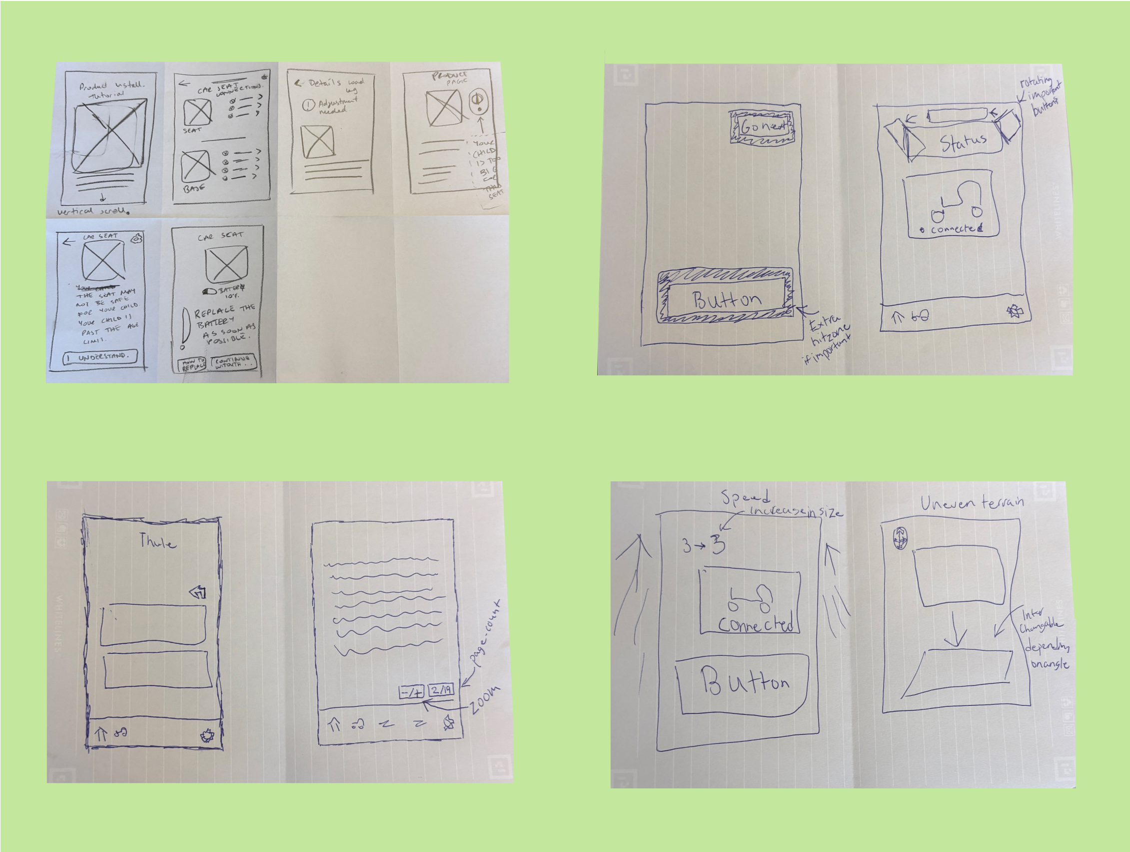

Figure 4.8: Sketches from the first session of Crazy 8's

Session 2: Rapid Divergent Ideation

The second session used a more exploratory, "let-loose" structure. Rather than sketching predetermined ideas, we employed the eight-minute format as a secondary brainstorming method to identify solutions through instant visual response. During this session, researcher 1 created six sketches, and the second researcher created four. This diverging stage attempted to overcome the internal filters of static design thinking in favor of more imaginative, context-specific solutions that had not yet been addressed.

The goal with this intentional move toward unconstrained ideation was to overcome cognitive biases caused by the current interface [71]. The session encouraged the investigation of extreme options that would have been rejected during more formal design stages by emphasizing speed and spontaneity. Before the project entered the prototyping stage, a wider range of options were taken into consideration thanks to the resulting sketches, which offered a diverse collection that complemented the work from the first session.

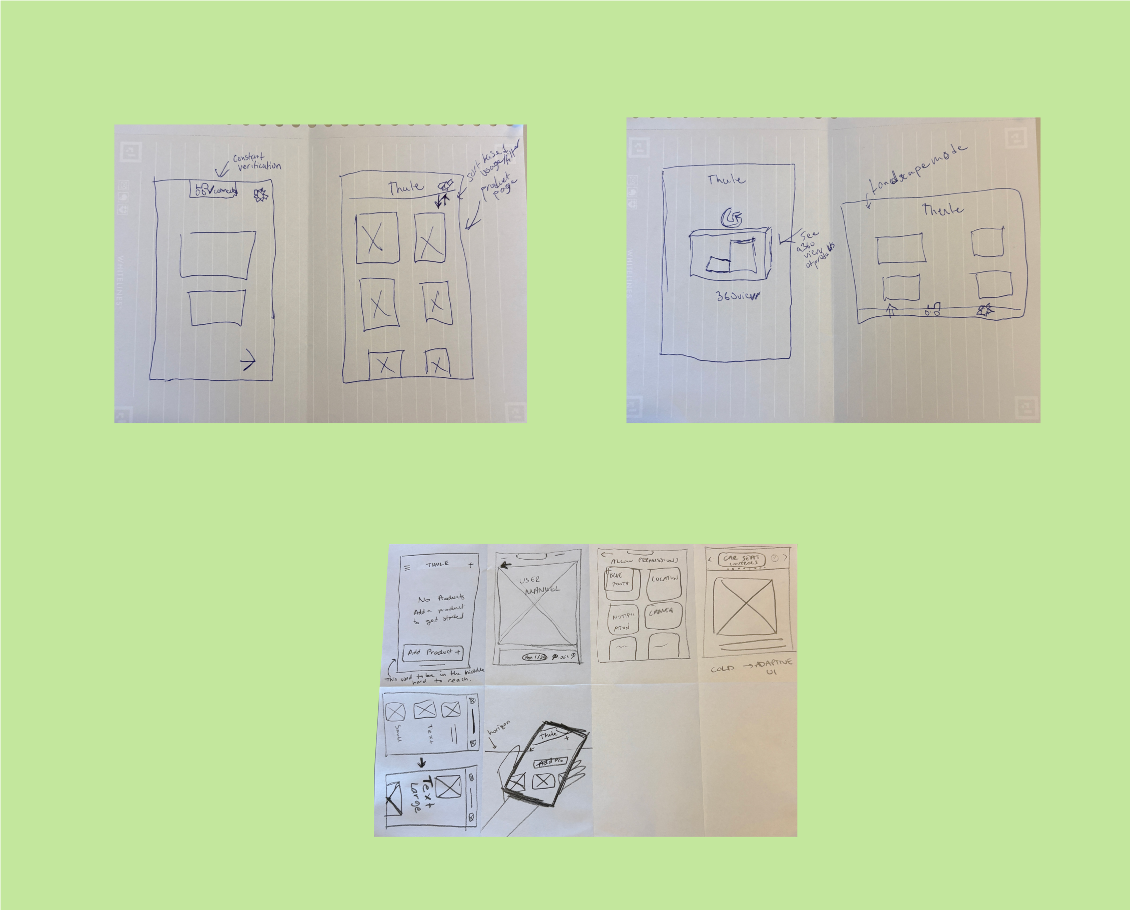

Figure 4.9: Sketches from the second session of Crazy 8's

Reflections on the Crazy 8's

While the Crazy 8's sessions yielded numerous viable design suggestions, the overall number of ideas was lower than initially expected. Unlike new projects, where designers have complete aesthetic and functional freedom, this study aims to retain brand consistency by working inside the company's established UI framework. This decision was made to guarantee that the end product was a genuine and feasible progression of the existing product, rather than an abstract concept.

However, there was a noticeable cognitive barrier when this dedication to brand consistency was contrasted with the need to incorporate intricate accessibility features. This phenomenon can be explained by "functional fixedness" [72], a cognitive bias in which the researchers' familiarity with the current UI elements limited their perception of those elements in different arrangements [71]. The self-imposed obligation to adhere to the brand's visual identity likely caused a state of cognitive friction.

It was a deliberate methodological decision to stop the Crazy 8's process after two sessions. We produced a total of 22 sketches at the end of the second session, offering a wide enough variety of visual interpretations to meet the functional needs found during the KJ approach. At this point, it was concluded that more quick, low-fidelity sketching iterations would result in diminishing returns.

Furthermore, as the next step of the development phase, we chose to move straight into high-fidelity design within Figma, skipping the conventional intermediate stage of low-fidelity wireframing. The existence of a strong design system, coupled with the study's inherent temporal constraints, provided a logical justification for this adjustment. Rather than re-creating established components in a simplified, low-fidelity format, we decided to leverage existing design assets to maintain momentum and technical accuracy.

4.3.2 Prototyping - First iteration

The initial iteration concentrated on converting the concepts from sketches and brainstorming notes into formal graphical representations. It also foucesd on incorporating the knowlegde gained from the WCAG analysis and the app audit. Thule has a well-established design system that includes pre-defined mobile UI components and styles. These existing assets were used to preserve brand consistency. As a result, very limited low-fidelity prototyping was done beyond the original Crazy 8 designs. As discussed previously, the choice to shift fast to a high-fidelity prototyping was based on the fact that constructing comprehensive low-fidelity models from scratch would take more time than it was worth, given that professional components were already accessible.

The primary objective of this iteration was to improve usability and accessibility in dynamic environments by a series of practical incremental improvements rather than a complete visual overhaul. These environments, characterized by physical movement, varying light conditions, and the potential for one-handed device usage, required a focus on resilience and accessibility.

Environmental and Structural Adaptability

As shown in Figure 4.11 and 4.14, a thorough dark mode framework was implemented to address the environmental issues identified during the discovery phase. For instance, 22.7% of the survey respondents reported they experience significant screen glare when using their phones. Dark mode can reduce the screen glare and eye strain in low-light environments [73]. As shown in Figure 4.13 and 4.14, dedicated landscape orientation for the mobile app was also designed to support WCAG 2.2, Success Criterion 1.3.4. This guarantees that the interface remains functional and legible when the phone is placed in fixed mounts, such as stroller attachments or car cradles, where a vertical orientation may not be practical.

Motor and Precision Enhancements

This iteration also concentrated on "target size" and "reachability" to reduce motor-related difficulties. As shown in Figure 4.11-4.14, the buttons (and their hitboxes) in the navigation bar were enlarged in accordance with WCAG 2.2 Success Criterion 2.5.8 to guarantee that they could be reliably pressed when the user is moving. To improve one-handed handling, crucial interactive elements shown in Figure 4.11 were moved to the lower quadrant of the interface, known as the "thumb-zone". The product manuals page also received an accessibility improvement. Zoom-in, zoom-out, and PDF page navigation buttons were added to the PDF viewer, on top of

Figure 4.10: 3D Render of one-handed mobile usage

the conventional pinch-to-zoom action. This change gives users more precise control over the PDF viewer, particularly meeting the needs of users who could be operating in unstable environments or have limited manual dexterity.

Overview of Design Changes The specific changes made during the initial high-fidelity iteration are described in the ensuing subsections. Every modification is a direct, research-driven response to the needs found in the initial accessibility audit and the KJ approach. Although this section discusses ten exemplary screens, Appendix C contains the whole set of designs created during this iteration.

Target Size and Thumb-Zone Optimisation

The iteration gave tactile precision and reachability top priority in order to address motor-related issues. The interactive hitboxes in the navigation bar were enlarged from the WCAG 2.2 AA minimum of 24px to a more accessible 32px in accordance with the improvements in Success Criterion 2.5.8 (Target Size). This change, which can be seen on all of the displays in Figures 4.11 through 4.14, guarantees that primary navigation triggers can be consistently triggered while the user is moving or has diminished manual dexterity.

Important parts were also moved to the "thumb-zone" for safer one-handed handling. The "add product" Call-to-Action (CTA) on the Home page (Figure 4.11, left) was repositioned from the center of the screen to the bottom. Similarly, the interactive product component that points the user to certain product information was moved to the lower quadrant of the Product page (Figure 4.11, center and Figure 4.12, left). These components were in the middle of the display in the previous application; by moving them to the bottom, the design removes needless reach-extension in a previously underutilized section of the screen.

Product Manual PDF Reader

To support customers who have trouble with high-precision gestures, a major functional change was made to the Product Manual interface (Figure 4.12, right). Users had to rely on "pinch-to-zoom" interactions and manual scrolling to navigate documents because the current PDF viewer lacked integrated controls. High levels of

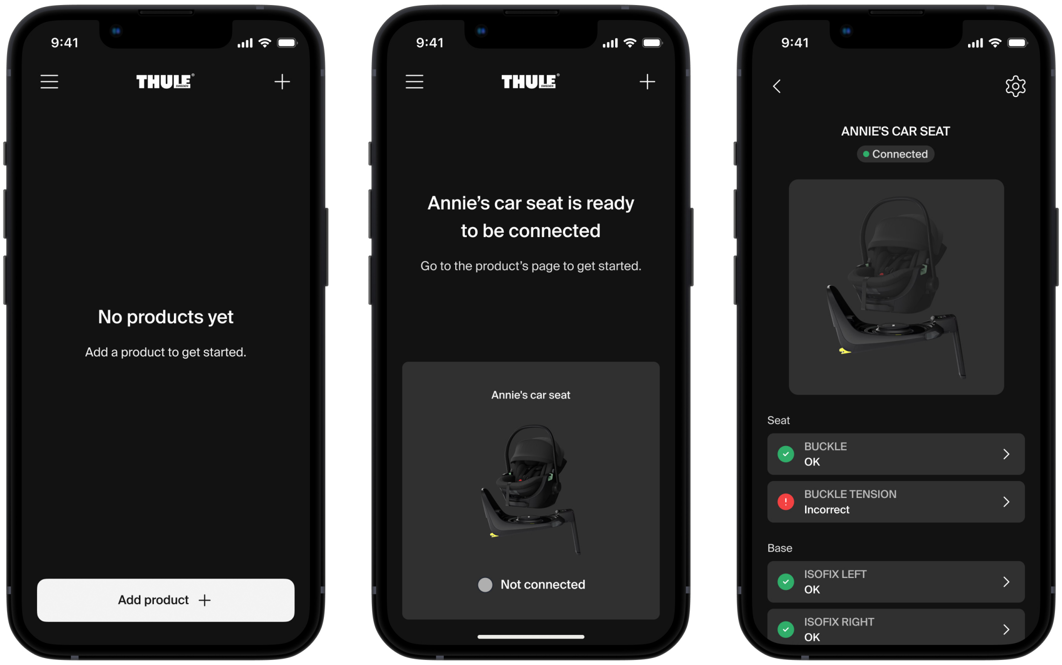

Figure 4.11: Iteration 1, Design changes for dark mode in portrait orientation

fine-motor coordination and the use of both hands are necessary for these motions, which can be challenging in dynamic settings.

A new control element was added to lessen this obstacle. In addition to a page counter that enables discrete, single-tap scrolling, this interface has distinct "Zoom In" and "Zoom Out" buttons. The prototype gives users more precise control over the document by substituting straightforward button-driven controls with intricate multi-touch gestures, guaranteeing that the PDF reader will continue to work when used with one hand.

Landscape Orientation

The iteration includes a landscape orientation after realizing that the application may be used in fixed-mount situations, like car cradles or stroller handles. When the device's physical positioning is limited, the Thule application's inability to allow horizontal viewing may frustrate some users.

For the Home and Product pages, specific landscape layouts were created, as shown in Figures 4.13 and 4.14. By guaranteeing that the information architecture reflows logically when the device is rotated, this structural update directly supports Success Criterion 1.3.4 (Orientation). This keeps the user from being compelled to look from a single, possibly uncomfortable angle when engaging in physical activity.

System-Wide Dark Mode

A thorough Dark Mode foundation was applied to all rebuilt displays as a last degree of flexibility (Figures 4.11 through 4.14). The lack of a low-luminance option in the

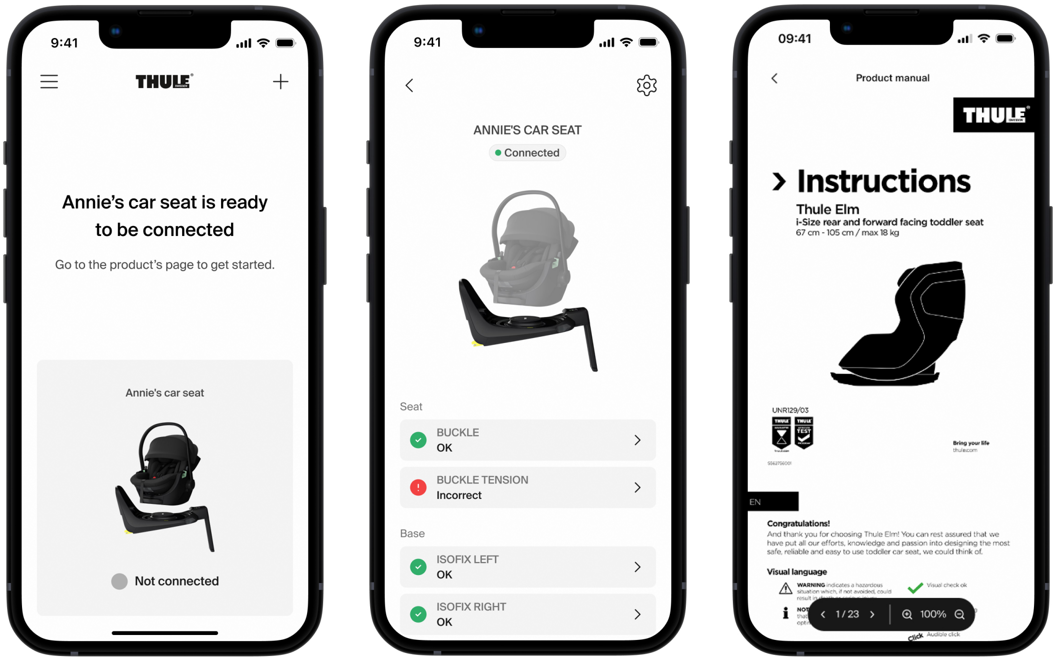

Figure 4.12: Iteration 1, Design changes for light mode in portrait orientation

current application poses serious obstacles for the 22.7 percent of survey participants who said they had trouble with screen glare.

This dark mode variation is a practical solution to outdoor illumination issues rather than just a decorative feature. The interface aims to minimize eye strain and retain readability in low-light environments by using a high contrast, low brightness palette. This system-wide inversion effectively bridges the gap between situational requirements and brand identification by guaranteeing that the application stays a dependable tool regardless of the external illumination conditions.

4.3.3 Evaluation of the First iteration - RITE

The first iteration was evaluated using qualitative usability testing inspired by the RITE method. This formative evaluation aims to evaluate the first iteration design by allowing participants to interact directly with the prototype. Unlike quantitative methods, this qualitative approach was chosen to provide in-depth insights into the "why" of user behaviours and to identify specific friction points within the new accessibility features. The rapid pace of the RITE method also matches the iterative nature of the prototyping process.

Rather than aiming for wide statistical generalizability, this phase employed a convenience sample of two individuals to produce designerly knowledge through direct engagement with the high-fidelity prototype. The emphasis is on finding fundamental ergonomic difficulties that arise when an interface is subjected to physical pressures. According to Nielsen [74], a small number of participants is frequently

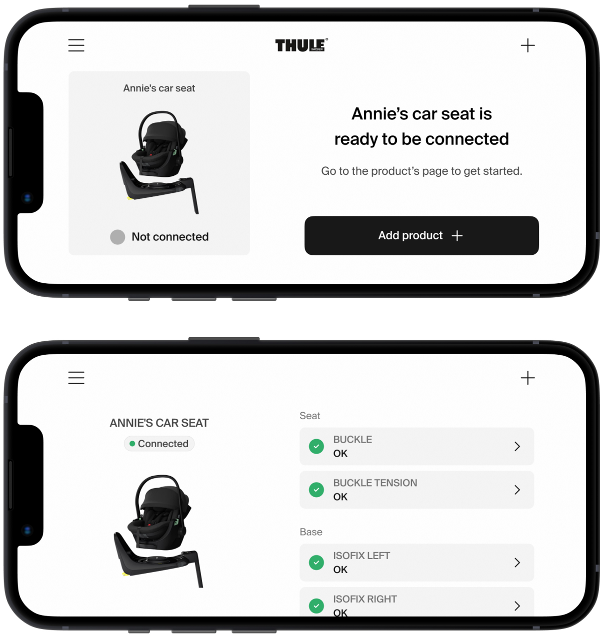

Figure 4.13: Iteration 1, Design changes for light mode in landscape orientation

sufficient in formative usability engineering to disclose the majority of high-level interaction obstacles, making it very successful for finding important faults prior to further design iterations.

A mobile device running a semi-interactive Figma prototype was used for testing. The participants were asked to walk and handle objects with one hand as part of the researchers' simulation of a dynamic environment. This configuration was essential for evaluating the interface's physical ergonomics, especially the navigational elements' reachability and the larger hitboxes' tactile efficacy. The study maintained strong ecological validity with regard to one-handed usage and the practical "thumb-zone" limits by testing on an actual mobile device.

The prototype was divided into unique user flows, each with a specific screen sequence, to provide a concentrated testing environment. These flows were created especially to depict the most important user journeys, such as reading particular product documentation or browsing the home screen. The assessment might more closely mimic how a user would naturally use the program to accomplish a goal by depicting the interface as a sequence of connected routes rather than discrete displays.

Two participants in the study interacted with these flows using a mobile device. Participants were required to carry out particular tasks within the flows, including: Imitating bodily movement when navigating the main UI, testing the new PDF controls by interacting with the product documentation with one hand and alternating between landscape and portrait orientation to assess the information's structural reflow.

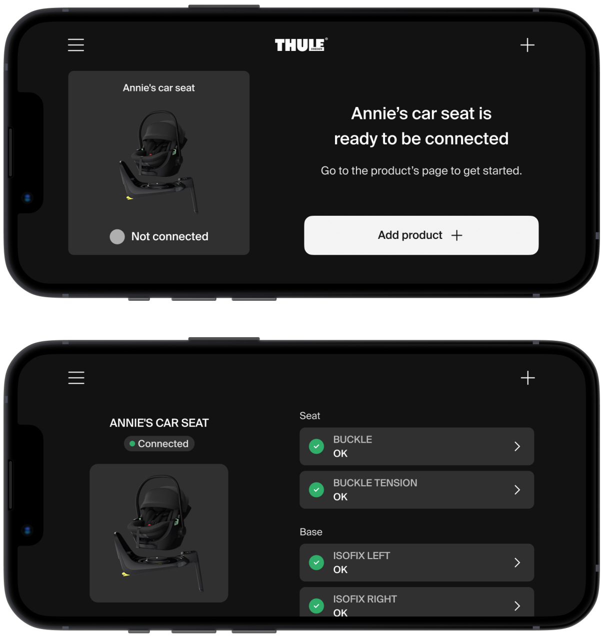

Figure 4.14: Iteration 1, Design changes for dark mode in landscape orientation

Each participant underwent a semi-structured interview after the task-based exchanges. This framework guaranteed that a number of important subject topics were covered while allowing for an open-ended investigation of the user experience. These sessions will yield qualitative data that will be used to detect design problems and guide the next iteration's changes.

Analysis of the evaluation

A deductive method was used to analyze the qualitative data from the evaluation session, categorizing participant comments into three main design objectives: environmental adaptability, ergonomics, and motor accuracy.

Ergonomics and Thumb-Zone Optimisation

It was validated that moving the "Add Product" CTA to the bottom quadrant was an effective ergonomic adjustment. The bottom-aligned location felt natural and intuitive to both participants, especially for those with tiny hands. However, the top-aligned navigation bar remained a point of friction. While the "Add Product" button effectively used the thumb-zone, one participant stated that they needed to alter their grip in order to reach the top of the screen to access the navigation bar. This suggests that the navigation bar still posed a difficulty to one-handed use. However, it's interesting to note that the same responder said they accept this friction since they consider the top navigation to be a standard design pattern.

Motor Precision and Error Tolerance

Interaction during simulated movement was enhanced by using negative space around icons and increasing target sizes to 32 pixels. According to participants, the absence of crowded clickable items reduced accidental triggers when walking, and they found the layout to be forgiving. This demonstrates that by offering adequate tactile precision for dynamic situations, the design met the goals of Success Criterion 2.5.8.

Another important accessibility feature was the addition of distinct zoom and navigation buttons in the PDF viewer. Participants recognized the buttons as the better option for one-handed or multitasking situations. However, participants stated that in situations where they can use two hands, they preferred the pinch-to-zoom gesture because it allows for more precision. This suggests that although having buttons to navigate PDF files is a useful accessibility feature and addresses the limitations of standard touch gestures, the application should employ both features to allow users to choose the appropriate one for the situation they are in.

Environmental Adaptability

The dark mode theme was deemed appealing by the participants. One participant claimed that while both the light and dark modes work as intended in low light conditions, the dark mode was "easier on the eyes" and hence more enjoyable. This may indicate that for some users, the addition of dark mode is more hedonistic than utilitarian. Elaborating further on the hedonistic aspect, participants reported that the change from light to dark modes felt well-executed and coherent. Both participants associated Thule's high-end brand identity with its practical, simple UI (in both light and dark modes).

The landscape orientation was praised for its "website-like" clarity, particularly for viewing detailed product information. Both participants agreed that the structural reflow was consistent and clean, meeting the requirements for Success Criterion 1.3.4. However, one participant expressed uncertainty regarding its functionality compared to portrait mode.

4.3.4 Process and Analysis of Contextual Inquiry

Following the first iteration, it became clear that there were more design possibilities that could be explored, particularly by grounding the process in the users' actual, lived reality. Because the Thule app product ecosystem is predominantly centered on products for parents, this demographic was recognized as a target for further analysis. This focus was narrowed to parents navigating with strollers, in part because the connected air filter, one of the core products integrated into the Thule App, is a primary example of an active, mobile use case. To address the consequent demand for situational nuance, the research approach resumed the Discover phase with a targeted contextual inquiry. The study went beyond the static data points from the survey to monitoring parents in the active scenario of navigating strollers in real time to ensure that the added criteria were based on the actual world's true constraints and environmental elements. This iterative method enabled a more open-minded investigation of how a parent genuinely engages with a digital hub.

The contextual inquiry took place in Slottsskogen in Gothenburg [75], an active and vivid park where lots of families visit every day to appreciate the nature. By observing and interacting with parents in this real-world setting, the research expanded beyond the static data points of earlier surveys. The major purpose was to explore the target demographic and their unique use cases in a live environment. This iterative approach enabled an open-minded exploration into how a parent truly connects with a digital hub while managing physical hardware within the limits of a public park. Finally, documenting this lived experience laid the groundwork for the subsequent Develop phase, ensuring that the design requirements were based on real-world restrictions rather than idealized behaviors.

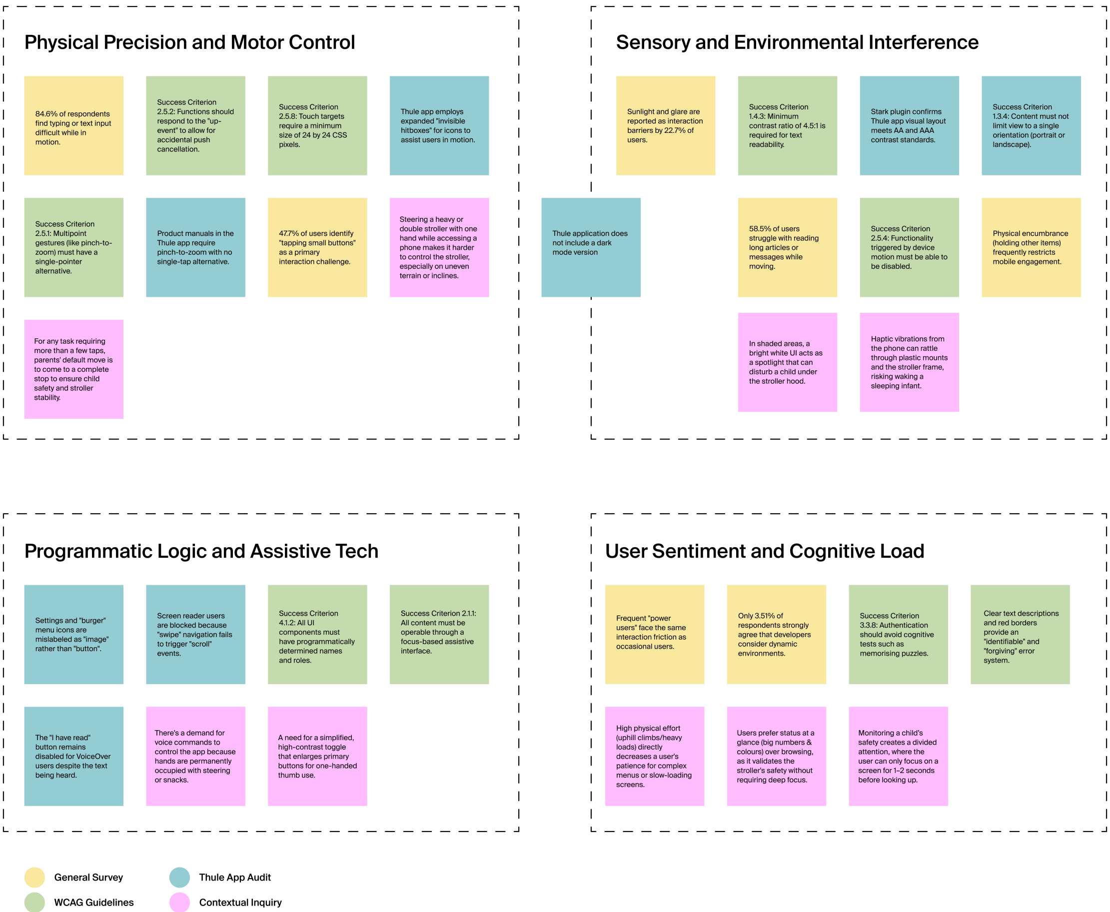

Figure 4.15: The updated Affinity Diagram with new data points from the contextual inquiry.

The contextual inquiry yielded findings that were incorporated into the affinity diagram developed during the first define phase. Using symbols for causation (→), conflict (↔), and correlation (- - →), this iterative mapping procedure employed the established KJ structural logic to ascertain how the newly observed stroller-specific behaviors related to preexisting data points. The study went beyond general assumptions to pinpoint particular situational limitations related to mobile parenting by reassessing the relationship map using these live-environment data points. Figures 4.15 and 4.16 show this revised hierarchy.

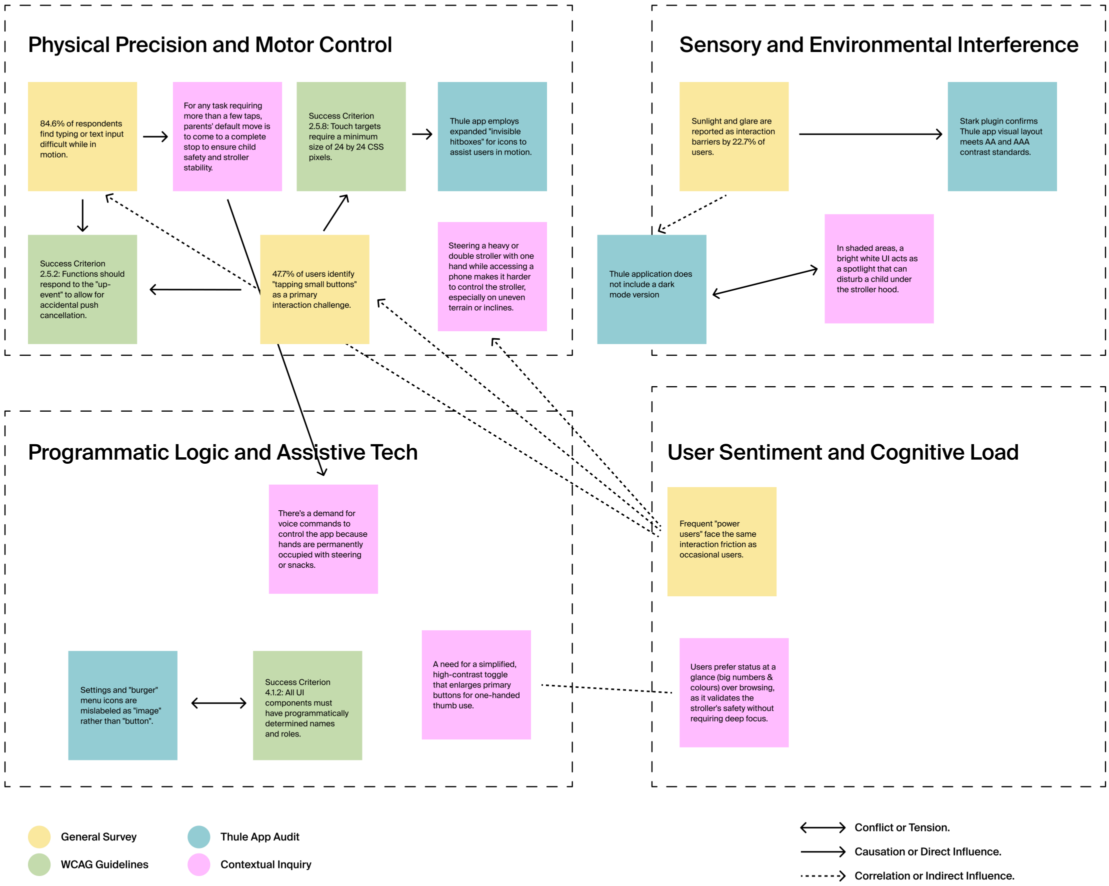

Figure 4.16: The updated Relational Map with new data points from the contextual inquiry.

4.3.5 Process and Analysis of Targeted Survey

The respondent group for the survey was made up entirely of pilot testers who were field testing the Thule back sensor and integrated child safety seat. These participants gave in real-life feedback (subjective data obtained in the actual context of use) about their encounter with the latest version of the Thule app.

The data collecting phase was carried out using a systematic process aimed to increase involvement within the purposive sample. To reach the intended group of pilot testers, the survey was delivered using a dedicated group chat, an established communication channel utilized by participants throughout the Thule back sensor and child safety seat testing phase. According to Lynn [51], using a specific, pre-existing communication medium is an important component of targeted survey processes since it reduces non-response by bringing participants into a contextually appropriate digital environment. This direct method meant that the survey was instantly available to people with hands-on experience with hardware-software interaction.

The survey was open for one week, giving participants enough opportunity to reflect on their use of the mobile application throughout their regular routines. The survey included 7 Likert-scale questions that span from 1 to 5 (Strongly Disagree - Strongly

Table 4.2: Results from the Likert-scale items in the Targeted Survey ($N = 16$)

Metric	**Mean**	**Median**	**Std. Dev.**
Setup Process	4.19	4.0	0.83
Info Visibility	3.88	4.0	1.09
Readability	3.81	4.0	1.22
Personalization	3.81	4.0	0.75
Error Logic	3.75	4.0	1.00
Content Reachability	3.56	3.5	0.63
Mounted Device	3.50	3.0	0.82

Agree). The questions within the survey are shown in Appendix F. During this time, a total of 16 people completed the survey. Although this is a tiny, non-probability sample, Etikan et al. [76] argue that in purposive sampling the validity of the data is determined by the participants' deep knowledge and relevance to the study aims, not the mere number of respondents. By concentrating on these 16 pilot testers, the approach collected technical and experience data that is directly connected to Thule app design.

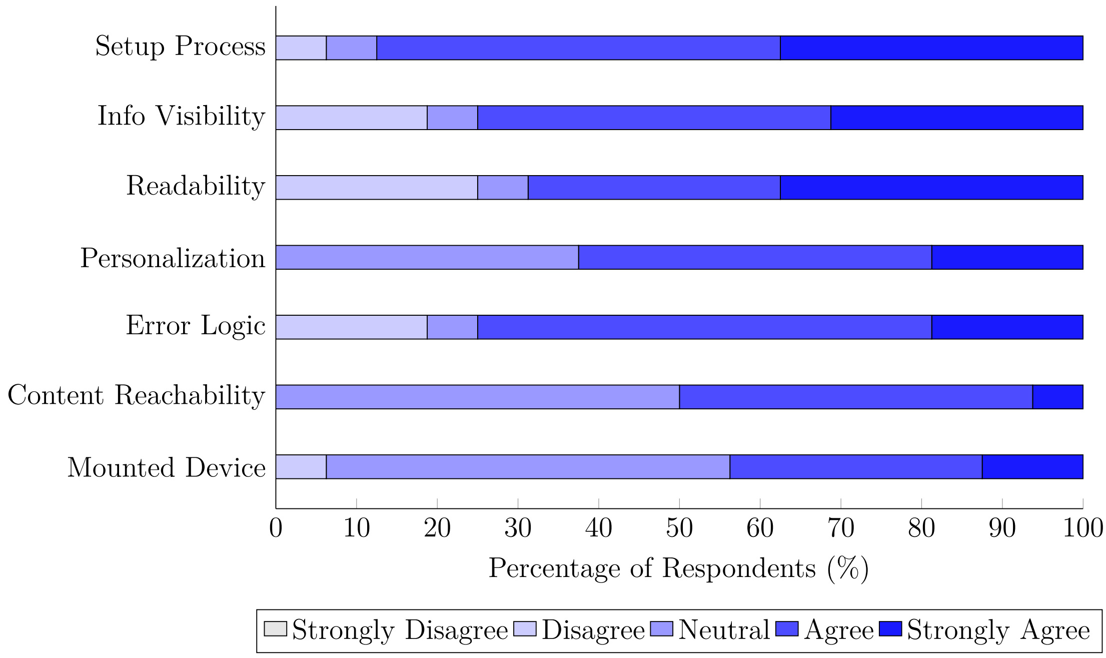

Figure 4.17: Frequency distribution of UX/UI sentiment for Thule mobile app ($N = 16$).

The data presented in Table 4.2 and Figure 4.17 show a clear distinction between static onboarding and dynamic operational usage. The Setup Process was the best-performing measure (mean: 4.19), indicating that the initial hardware-software "handshake" is straightforward and well-optimized. However, when the user progresses to active, hardware-interfacing circumstances, there is a considerable decline in tendency. The Mounted Device metric obtained the lowest score (Mean: 3.50), suggesting that the interface is still not sufficiently adaptable when the phone is placed in a vehicle cradle or stroller handle. This lack of adaptability is further demonstrated by Content Reachability (Mean: 3.56), which emphasizes the physical difficulty of engaging with the UI when multitasking or moving.

A crucial insight is provided by the large variance reported in Readability (Std. Dev: 1.22), the dataset's greatest standard deviation. This polarization implies that, while the existing UI serves many users well, it performs sub-optimally in particular environmental contexts. This finding is also included as a data point in the updated KJ diagrams, shown in Figure 4.18 and Figure 4.19.

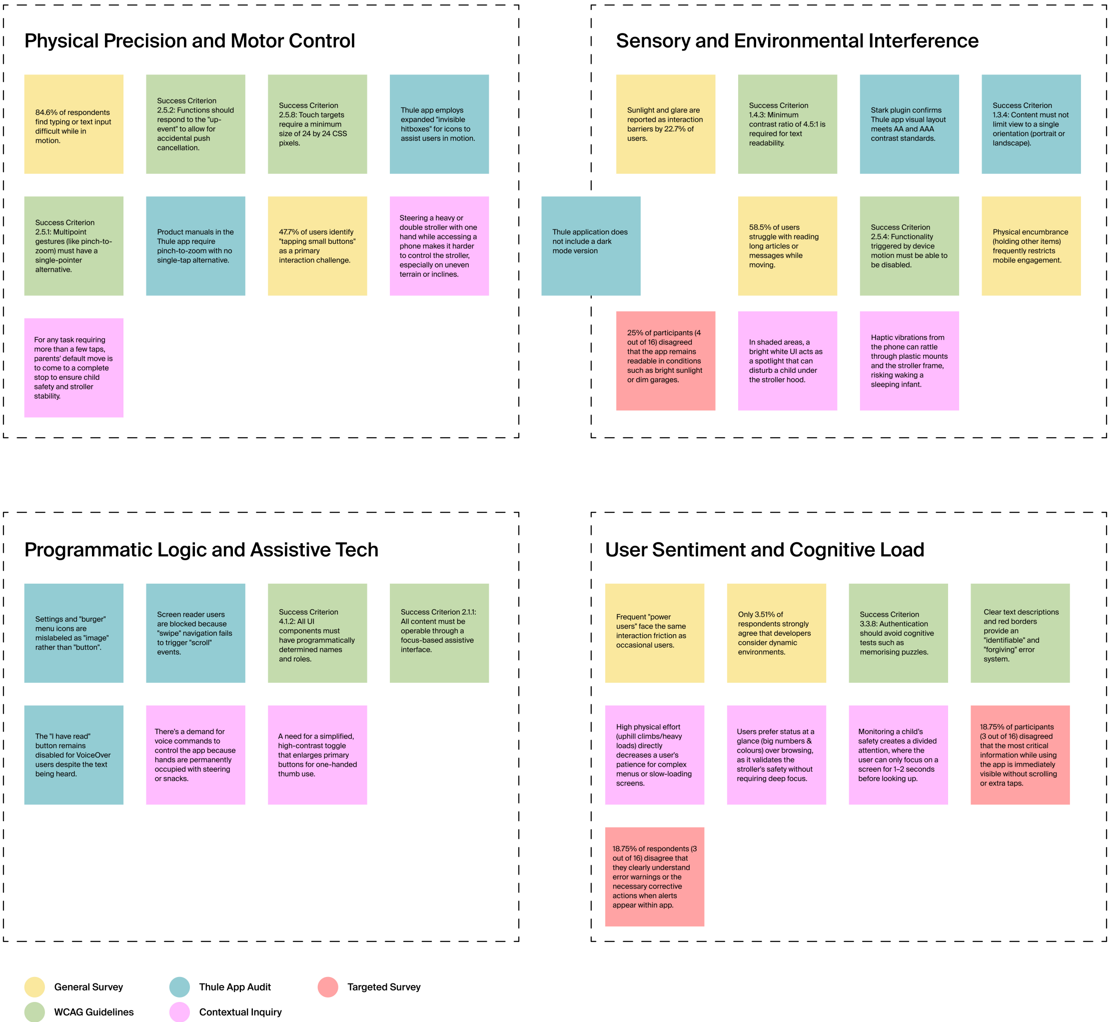

Figure 4.18: The updated Affinity Diagram with new data points from the targeted survey.

4.3.6 Prototyping - Second Iteration

The second iteration, which builds on the grounded data gathered from the evaluation of iteration one, the contextual inquiry and the updated hierarchy of the affinity

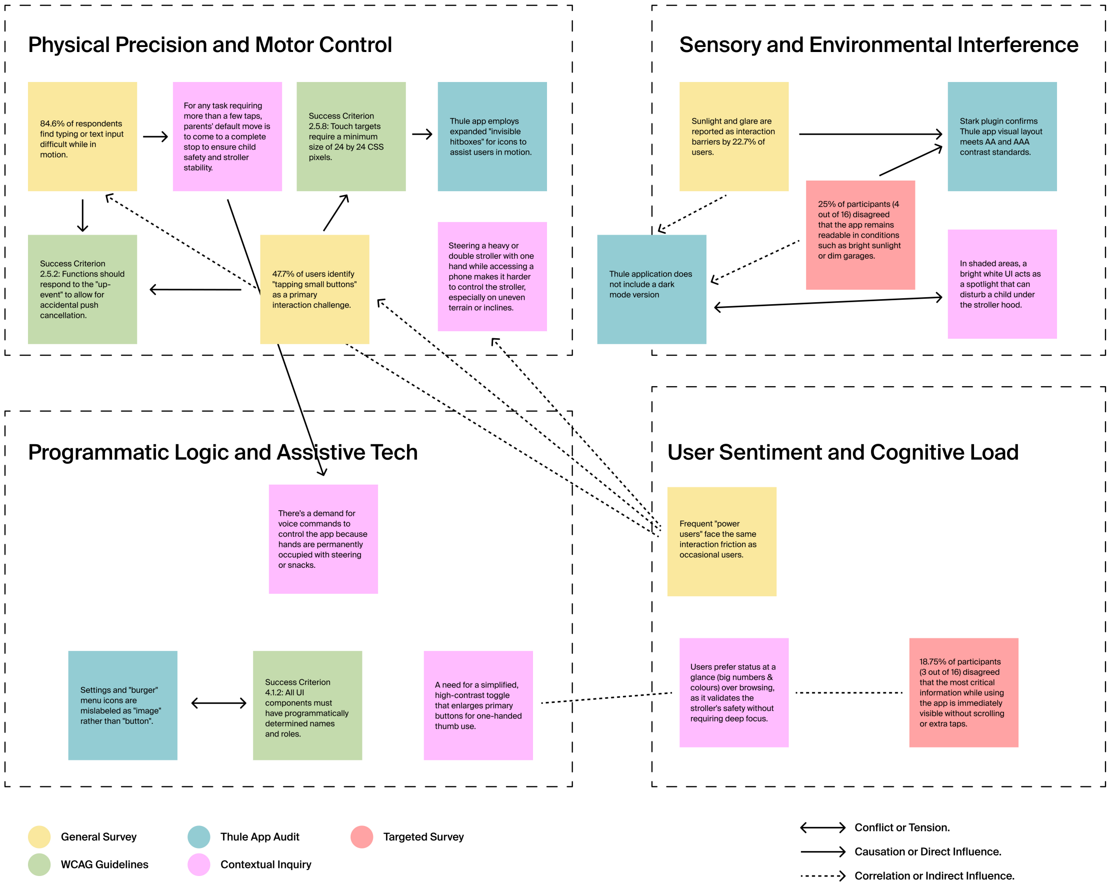

Figure 4.19: The updated Relational Map with new data points from the targeted survey.

map using the KJ method, focuses on the practical reality of parenting and controlling a phone. While the first iteration defined an updated version of the Thule app's functional and technological architecture, the second iteration specifically focuses on improving the user interface and user experience for active scenarios.

While based on the findings from the first iteration, the second iteration employs creative freedom to solve the situational gaps observed in the field. As a result, the suggested Active Mode integrates design solutions that go beyond established brand guidelines, guaranteeing that usability in active scenarios is prioritized over regular design system limits.

4.3.6.1 Active Mode

Active Mode is a specialized interface toggle that aims to improve usability in high-motion settings. This custom theme addresses the physical constraints that parents and active users have, such as reduced dexterity when pushing a stroller, one-handed operation in transit, or the necessity for quick, glanceable information while driving.

Active Mode minimizes the cognitive burden necessary to engage with the device by prioritizing core functionalities with larger tap targets and a high-contrast color palette. This ensures that critical controls are still available even when the user's primary focus is on their surroundings or their child's safety. The mode functions as a functional overlay, reducing the complex design of the normal app to a simpler experience that prioritizes functionality over aesthetics.

Although the Thule application contains more screens than just the product home page, it is the primary screen that users interact with after their device is linked to a product. As a result, the designs for the active mode were mostly focused on the product home page. It is also important to note that Active Mode is not limited to Thule strollers. It is an integrated feature of the application as a whole, allowing users to toggle the mode on and use it to control any product in the Thule application.

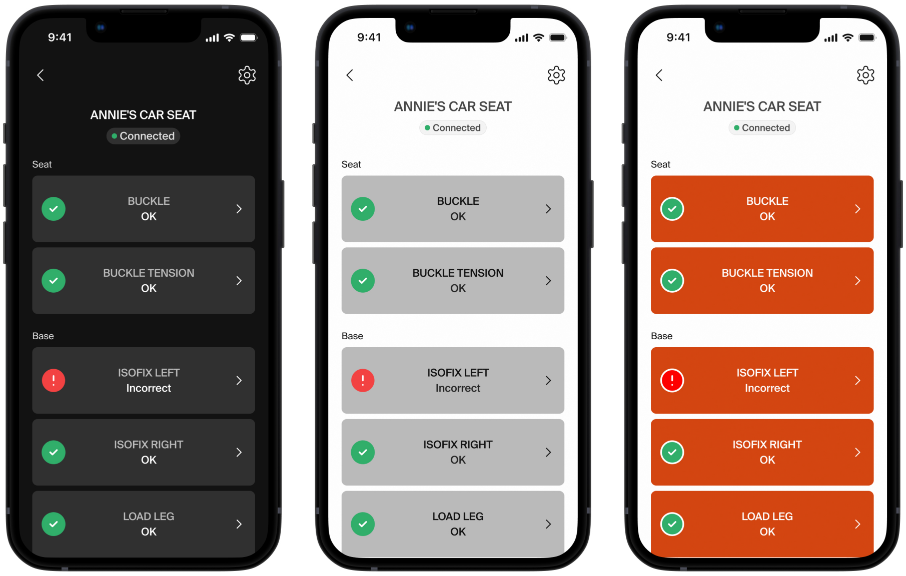

Figure 4.20: Design explorations for product home page with Active Mode

Function over form: To minimize the cognitive load during high-motion activities, product images were removed from the interface. By prioritizing function over form, the design minimizes non-essential visual information that could distract a user in a glanceable scenario. While it is argued that functionality and aesthetics play an equal role in creating a pleasant user experience [77], the specific context of mobile parenting necessitates a tactical shift toward functional clarity. This simplification keeps the layout tidy and directs the users attention solely to the data and controls required for the current task, such as monitoring product status or modifying settings while in motion.

Larger buttons: The primary aim of the redesign was to significantly increase the size of the primary interactive elements. Buttons were redesigned with considerably bigger touch zones to compensate for the reduced dexterity that users feel when moving or handling the phone with one hand. Fitt's Law [78] states that the time required to move to a target is determined by the ratio between the distance to the target and the width of the target itself. These larger touch zones reduce the precision necessary to execute a task, lowering the possibility of accidental inputs and ensuring that important controls are still accessible even when the user is physically distracted. One of the interviewees from the contextual inquiry stated "*I would definitely appreciate larger buttons in general since I have large hands, I often find smaller buttons a bit frustrating to navigate accurately.*"

Distinct color: The use of a distinct, high-contrast orange colour acts as both a functional tool and a visual signifier. From a usability standpoint, vibrant orange enhances the visibility of essential functions and status indicators, making them easier to detect in different lighting conditions. Furthermore, this particular colour choice gives the Active Mode a unique look, providing the user with a quick mental image of the app's current status. This makes the active mode immediately recognizable from the regular theme of the app, confirming the shift to a high-performance interface.

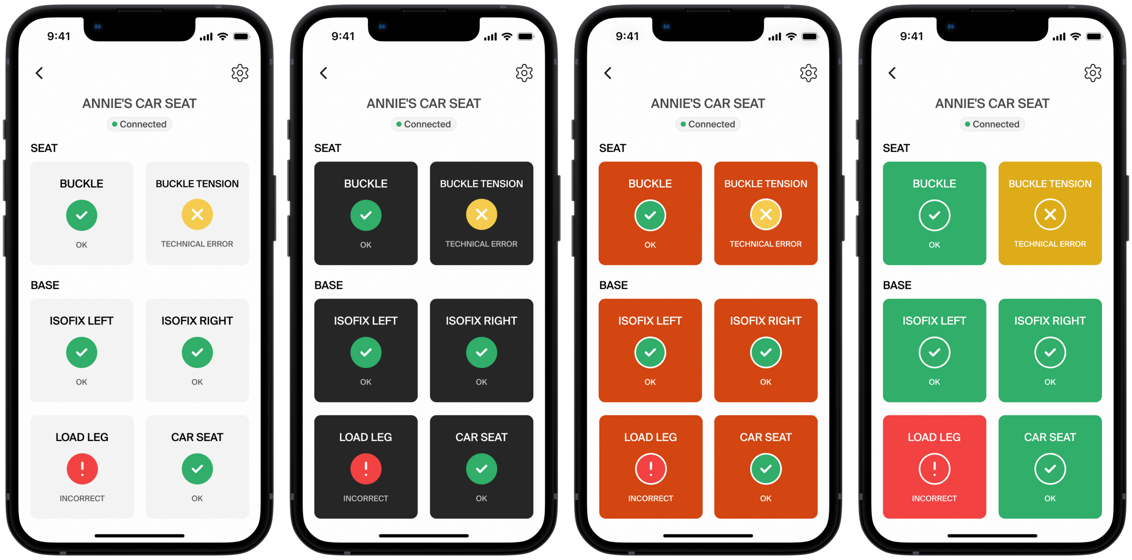

Figure 4.21: Design explorations for product home page with Active Mode

Following the initial changes to tap targets and colors, a secondary design exploration was conducted to determine how structural layouts and uses of colors could further improve the user experience of the product home page in active circumstances. These designs are focused on condensing information and providing the user with immediate feedback.

Non-scrolling screen: This exploration employs a grid-based architecture to ensure that all necessary controls and status indicators are contained within a single, non-scrolling screen. By eliminating the need for vertical scrolling, the design aims to make it easier to use the app while in motion. This one-screen method ensures that the most relevant information is constantly visible, preventing critical data from being hidden behind a scroll during active scenarios with limited precision and attention.

Legible information: Both typography and iconography were scaled up to support users who can only glance at the phone. By increasing the size of the text and icons, the interface favors legibility above information density. This not only allows users to quickly read status updates and identify functions, but also allows them to do so from a distance, such as when the phone is attached to a stroller or a car.

Status Colors: The use of full-frame backdrop colors to indicate system statuses marks a substantial departure from previous explorations. While typical interfaces frequently use small symbols to convey status, this design uses green, yellow, and red to cover the whole backdrop of a frame to symbolize "OK", "Incorrect", and "Technical Error", accordingly. It is intended to convey a quick, awareness of the product's status. Employing the full frame as a visual signal may lead to easier handling, which will help the user to assess the status and make the experience smoother.

Color Vision Accessibility: While the use of high-contrast orange and status colors (green, yellow, and red) is intended to improve glanceability and functional clarity, the implementation must be compatible with the realities of visual impairments. The reliance on a red-yellow-green paradigm creates major accessibility challenges for users with color vision deficiencies (CVD), particularly protanopia and deuteranopia (red-green blindness) [79], who struggle to discern between these precise spectral hues. According to Jenny and Kelso [79], designing for the color vision impaired entails avoiding color combinations that collapse into indistinguishable shades of brown or gray. To ensure that Active Mode remains inclusive and functionally robust, these background status colors cannot rely solely on color for status updates. They must be combined with redundant visual signifiers, such as distinct geometric icons and explicit text labels, to ensure that critical safety and technical errors are instantly recognizable to all users, regardless of visual acuity.

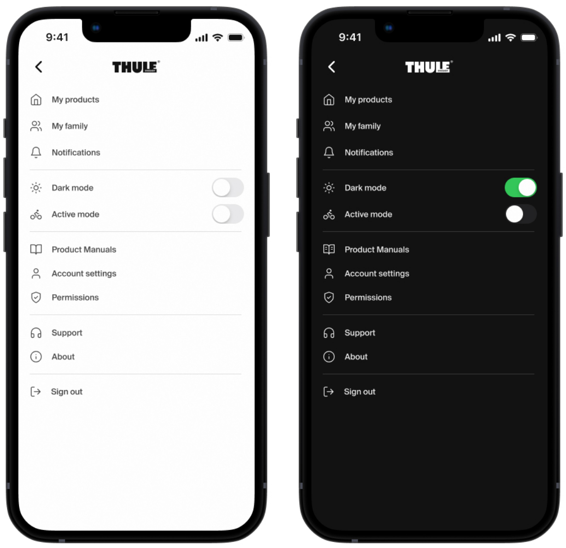

Figure 4.22: Updated settings page, regular mode

As shown in Figure 4.22, the existing settings page has been updated to include Dark Mode and Active Mode options. The layout of the page remained the same, with only two additional texts and toggle buttons. The two designs shown are for the "default" state (when the Active Mode is turned off) of the app.

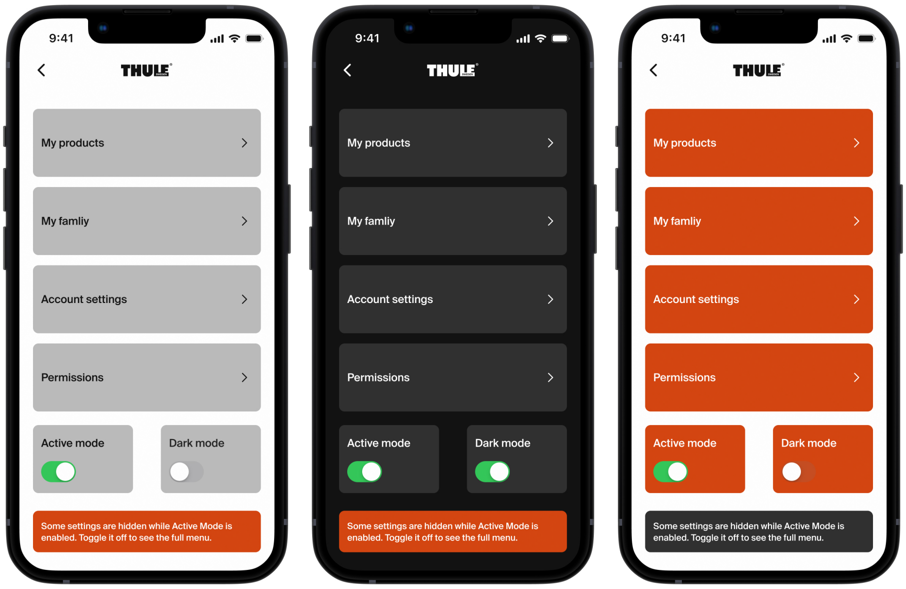

Figure 4.23: Updated settings page with Active Mode turned on

Figure 4.23 showcases the design of the settings page when Active Mode is on. As discussed earlier with Figure 4.20 and 4.21, the Active mode employs larger buttons and text. An important design choice was to hide certain options within the settings page when Active Mode is turned on. The rationale behind this decision was to reduce clutter, and present the user with the most relevant information/options. It also allowed the information to fit into a non-scrolling screen, while also maintaining large button and text sizes. At any point, users can turn off the active mode to access the rest of the settings.

5

Results

This chapter presents the study's findings, which begin with the limitations of WCAG 2.2, and the introduction of a comprehensive set of context-specific recommendations designed to ensure digital interfaces stay functional across a variety of dynamic user scenarios. Following these recommendations, the chapter describes the final high-fidelity prototype of the Thule mobile app, which serves as a practical proposal for implementing the research findings. Finally, the chapter offers a set of principles for developing app-specific recommendations.

5.1 Limitations of WCAG 2.2

The empirical data collected across the general survey, accessibility audit, and field observations identify clear functional limitations when the WCAG 2.2 are applied to mobile interfaces in dynamic environments. While the current Thule application satisfies several core metrics, such as minimum contrast ratios (SC 1.4.3) and target size containers (SC 2.5.8), the results demonstrate that strict compliance with these criteria does not guarantee usability when users are in dynamic environments.

Quantitative analysis reveals a direct conflict between standardized thresholds and physical motion. Although WCAG 2.2 specifies a minimum touch target size of 24 by 24 CSS pixels, 47.7% of general survey respondents ($N = 65$) cited tapping small buttons as a primary physical barrier to mobile utility on the go. Frequent power users report the same level of interaction friction as infrequent users, according to bivariate cross-tabulation, indicating that regular practice does not solve the precision problems brought on by walking and shaking devices.

Additional constraints are identified by qualitative results from the interface audit and contextual inquiry. Top-aligned components can pass technical audits even though they are totally out of reach when physically multitasking or pushing a stroller with one hand since WCAG 2.2 lacks structural design requirements governing the visual layout of inputs. Another important limitation is that conventional criteria assess content clarity under static assumptions, ignoring the information density, visual clutter, and complex navigation routes that lead to user distraction and cognitive overload during short, fragmented engagements in dynamic environments.

5.2 Context Specific Recommendations

The insights gained via the multiple analyses, iterative prototyping & testing cycles, and qualitative observations during the semi-structured interviews, as well as the surveys, serve as a foundation for developing the context-specific recommendations. The following recommendations have been developed to guarantee that the interface stays functional across a variety of user settings. These principles provide a link between immediate usability improvements and long-term design strategy, transforming direct participant feedback into a defined foundation for the application's further development, but also lay the foundation for broader implications across other apps. These recommendations are built on top of existing industry standards such as WCAG 2.2, and they should be viewed as an extension of WCAG 2.2, not a collection of standalone guidelines.

These recommendations were created through an ongoing, highly iterative process over the course of the research, as opposed to being produced as a static, final outcome of the thesis. The design artifact itself served as an active research and inquiry tool during the hands-on development of the high-fidelity mobile prototype, which was closely linked to the formulation of the recommendations. Preliminary rules derived from the theoretical WCAG analysis and initial surveys were directly applied to early design iterations, exposing the practical limitations of standard components when subjected to physical constraints in dynamic environments. The recommendations were challenged, expanded upon, and modified as a result of each data collection method's discovery of friction points. Thus, the final set of recommendations that follows is validated through combination of user-centered testing, empirical data, and iterative design exploration.

5.2.1 Thule App Final Recommendations

Prioritize the Thumb-Zone: *Place all primary Call-to-Action (CTA) buttons in the lower quadrant of the screen to enable safe, one-handed operation without requiring grip adjustments.*

According to research, users in dynamic environments, such as parents pushing strollers or holding children, rely largely on one-handed operation. During contextual query, participants mentioned that reaching the top of the screen requires them to change their grip, which is uncomfortable and difficult while one arm is occupied with steering. Moving key CTA buttons to the bottom quadrant reduces unnecessary reach and provides for safer, more stable engagement during physical activity.

Exceed Minimum Target Sizes: *While standard WCAG permits 24x24 pixel targets, dynamic use requires a minimum of 32x32 pixels to account for hand tremors or device shaking while walking.*

According to the general survey, 47.7% of respondents cited tapping small buttons as their main physical issue, despite the WCAG standardizing a 24x24 pixel minimum for touch targets. Environmental stressors and device vibrations greatly impair a user's fine motor precision when walking or multitasking. This decreased dexterity is compensated for by enlarging these interactive hit-boxes to a minimum of 32x32 pixels, which lessens the requirement for precise timing and minimizes unintentional inputs.

Increase Negative Space: *Provide ample breathing room around interactive elements to prevent accidental triggers during physical movement.*

An assessment of the first design prototypes showed that adding enough negative space around interactive icons effectively avoided unintentional triggers when participants were walking. The interface is much more accommodating for dynamic movement thanks to intentional negative spacing, which offers a high degree of mistake tolerance.

Optional Dark Mode: *Implement a high-contrast dark mode to reduce eye strain in low-light settings and minimize screen glare in bright environments.*

According to the general survey, 22.7% of users experience screen glare and bright ambient light, which severely affects screen visibility outside. In contrast, qualitative observations revealed that in dimly lit locations, a bright white user interface acts as a glaring spotlight, disturbing a sleeping newborn under a stroller hood or causing problems while parking using the rear sensor. Implementing a system-wide, high-contrast dark mode bridges these varied situational requirements by reducing eye strain, preventing temporary night blindness, and ensuring readability under a variety of lighting conditions.

Support Structural Reflow (Landscape): *Design interfaces that logically reflow when the device is rotated. This is critical for users who mount their phones on fixed-mount like car cradles or stroller handles.*

Mobile users frequently use fixed phone mounts in vehicles, which physically constrain the screen's orientation. The targeted survey of pilot testers revealed that interacting with a mounted device had one of the lowest usability scores, indicating a lack of structural adaptability. The interface should be designed to logically reflow into landscape mode, ensuring that the information is available without forcing the user to see the application from an inconvenient or unsafe position.

High Contrast Baselines: *Maintain a minimum contrast ratio of 4.5:1 for text and 3:1 for UI components to ensure legibility even when the user is dealing with SVIs like direct sunlight.*

Situational Visual Impairments (SVIs), such as intense sunlight, can significantly reduce screen image quality when using a device outside. As a result, users must use more mental energy to understand visual information. In order to keep the application readable and distinct even in high-glare situations, a rigorous minimum contrast ratio of 4.5:1 for all text and 3:1 for interface elements must be maintained.

Provide Single-Pointer Alternatives: *Never rely solely on multi-touch gestures like pinch-to-zoom. Always provide discrete, single-tap buttons for navigation* *and magnification to support multitasking users.*

Using multi-touch gestures like pinch-to-zoom provides significant functional challenge for users attempting one-handed operation or those with limited motor dexterity. In a dynamic environment, coordinating many fingers while also managing a child or physical hardware is quite difficult. Providing distinct, single-tap buttons for operations like magnification and page navigation allows users to have precise control without using two hands.

Disable Motion Actuation: *Ensure that features triggered by shaking or tilting the device can be turned off to avoid unintentional activation in dynamic contexts.*

Users who walk, ride a bike/vehicle, or push a stroller are continuously subjecting their devices to physical vibration. Because environmental motion is uncontrolled in active scenarios, any application feature that is activated by shaking or tilting must have an option to be disabled. This prevents the user from accidentally activating settings or interrupting their current task due to device movement caused by external factors.

Maintain Standard Design Patterns: *Use recognizable UI conventions for navigation. While you want to optimize for movement, straying too far into novel ideas can increase cognitive load when the user is already stressed.*

Users heavily rely on pre-existing mental models to navigate digital areas when they are physically or mentally burdened by their environment. Qualitative testing revealed that users readily accept minor ergonomic friction, such as top-aligned menus, specifically because it matches standard interface conventions. The user's cognitive burden is unnecessarily increased in high-stress conditions when they stray into unusual or "wild" visual arrangements because they must interpret unfamiliar layouts.

Implement a Dedicated Active Mode: *Provide an optional, simplified interface toggle that strips away non-essential visuals to prioritize quick, glanceable controls in high-motion environments.*

Active Mode is a specialized, optional interface toggle meant to improve usability in high-motion environments where users want quick, glanceable information. It works as a dedicated overlay, transforming the standard application into a simplified interface that prioritizes functionality over aesthetics. To accomplish this, non-essential visual features are removed to keep the layout uncluttered. This deliberate move from form to function significantly decreases the cognitive load on the user. By removing visual distractions, the interface focuses the user's divided attention entirely on key functions, using large touch targets and a high-contrast color palette to support quick and secure interactions in dynamic environments.

Consolidate Information to a Non-Scrolling Screen: *Try to fit all critical controls and status indicators within a single frame to eliminate the need for vertical scrolling during brief interactions.*

Users usually rely on quick, one- to two-second glances to keep track of application statuses during active scenarios. Vertical scrolling is successfully eliminated by using a grid-based architecture that condenses all required controls onto a single frame. This architecture decision guarantees that important safety settings and indicators are never obscured when the user's focus and accuracy are potentially compromised.

Provide Modular Sensory Feedback Options: *Include customizable haptic and audio cues to deliver important non-visual alerts when a user cannot safely look at their device.*

It is sometimes tough for people to safely look at their mobile screens while utilizing physical equipment or actively exploring their surroundings. Strong sensory input, such as haptic sensations or in-app audio status updates, is necessary to deliver significant non-visual clues. By combining these tactile and auditory cues, one could ensure that users receive crucial safety alerts and system confirmations instantly, even when their focus is diverted or their device is hidden. Giving users the option to deliberately alter or mute sensory outputs guarantees that the program adjusts to the social and physical limitations of their present environment.

Maintain State Retention: *Ensure the application preserves its exact state when the screen is locked to seamlessly support fragmented, frequently interrupted user sessions.*

Multitasking in dynamic environments often results in user's interactions being separated into short, interrupted sessions. Some participants expressed frustration when applications were reset to the home screen when the device is locked while their attention was interrupted. Guaranteeing that the app remains in the exact state in which the user left it prevents data loss and more importantly, accommodates the reality of frequent real-world interruptions.

Support Voice Command and Audio Updates: *Integrate hands-free interaction methods, such as voice controls and auditory feedback, for users whose hands and visual attention are occupied by physical tasks.*

A user's hands are frequently completely engaged when performing physical tasks, such as pushing a stroller, carrying groceries, or holding a child. Voice commands or in-app audio updates provide a vital accessibility bridge for people who wear headphones while navigating. This enables customers to engage with the application and get the essential status updates without ever having to look away or let go of their gear.

5.3 Thule Mobile App Proposed Final Design

This section presents the Thule mobile app's final high-fidelity prototype, which serves as a practical implementation of the previously established context-specific recommendations. These designs have evolved as a result of a design process that has two separate phases, iteration 1 and 2. Rather than depending on assumptions, these iterations were designed based on empirical data gathered during the research and development stages. This foundational data was obtained through a general user survey, Thule app accessibility audit, WCAG 2.2 analysis, qualitative usability testing, a real-world contextual inquiry, and a focused survey of pilot testers of the current Thule App.

5.3.1 Home Page

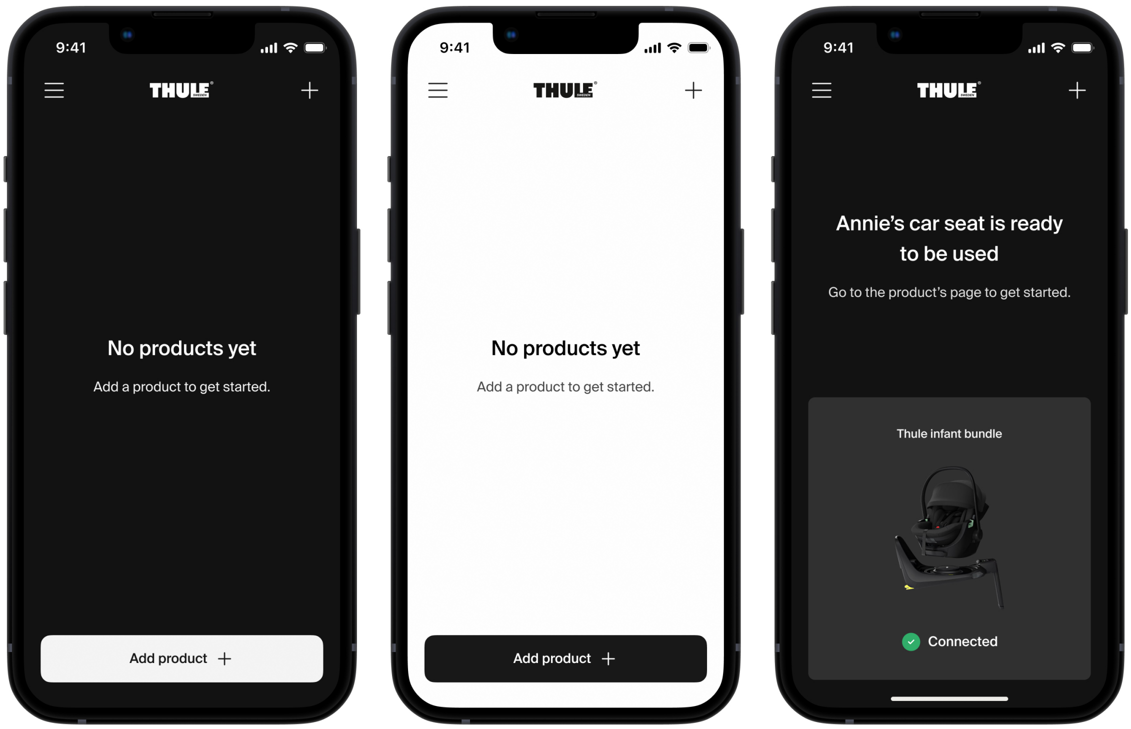

Figure 5.1: Proposed final design for the home page of the Thule app. Available in both dark and light modes.

As shown in Figure 5.1, redesign of the Home Page focuses on the physical limits of using a mobile device with one hand, which was based on our assumptions and experiences. Which was later validated during the evaluation of iteration 1, as well as the contextual inquery. To increase ergonomics, the major "Add Product" CTA button was moved from the center of the interface to the lower quadrant, firmly within the user's thumb-zone. This structural change eliminates the need for awkward grip modifications while multitasking, and it was widely appreciated for its natural feel during the evaluation sessions. Additionally, the interactive hitboxes for top navigation components were increased from 24 pixels to 32 pixels. This enhancement was driven by the general survey results, where 47.7% of users identified tapping small buttons as a primary physical challenge.

Furthermore, the Home Page has been redesigned to properly enable structural reflow in a landscape orientation (Figure 5.2). This design decision is in direct response to WCAG 2.2 Success Criterion 1.3.4. By allowing the interface to rotate and scale logically horizontally, users are no longer forced to interact with the application using the portrait mode, and have the option to use landscape mode when needed.

Lastly, the Home Page (as well as the entire application) offers a dark mode option in addition to the regular light mode. The need for this functionality was recognized in the general survey and the literature review conducted before the process started. While the light mode maintains great visibility in direct sunshine, the high-contrast, low-brightness dark mode is an important option for low-light situations, successfully reducing eye strain and preventing temporary night blindness. Qualitative feedback from the evaluation indicated that this modification was not only functionally useful, but also aligned with the brand's premium aesthetic. An important point to note about the proposed dark mode is that the prototypes use the existing product images, which were initially taken by Thule for the light mode version of the app. In some screens across the app, there isn't much contrast between the product images (such as the baby seat) and the background components. If the dark mode version is to be implemented by Thule, new product images need to be taken to be compatible with the dark mode color constraints.

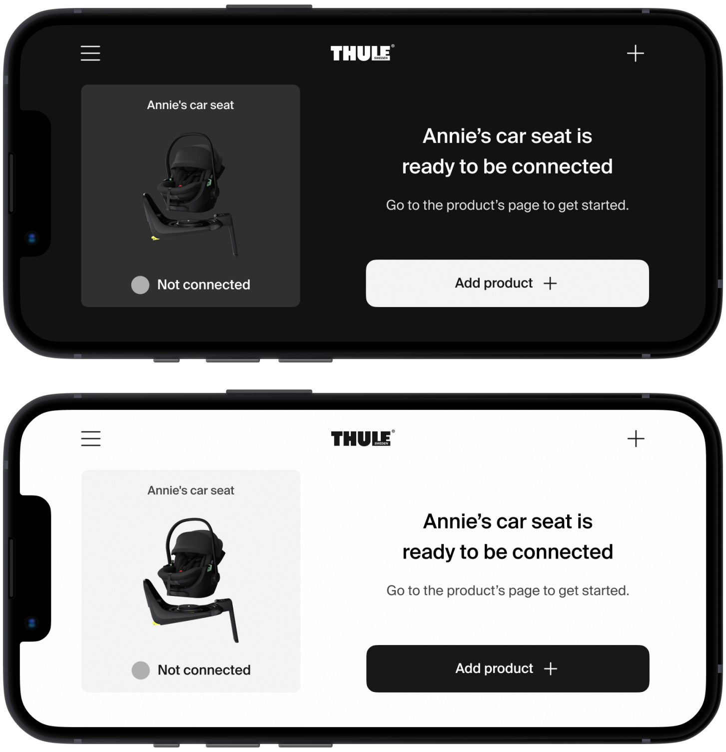

Figure 5.2: Proposed final design for the home page of the Thule app in landscape orientation. Available in both dark and light modes.

5.3.2 Product and Manual Pages

The redesign of the Product Page mostly included minor changes in order to maintain the brand identity. Navigation components' sizes have been increased as discussed previously, and a landscape orientation (Figure 5.4) was designed.

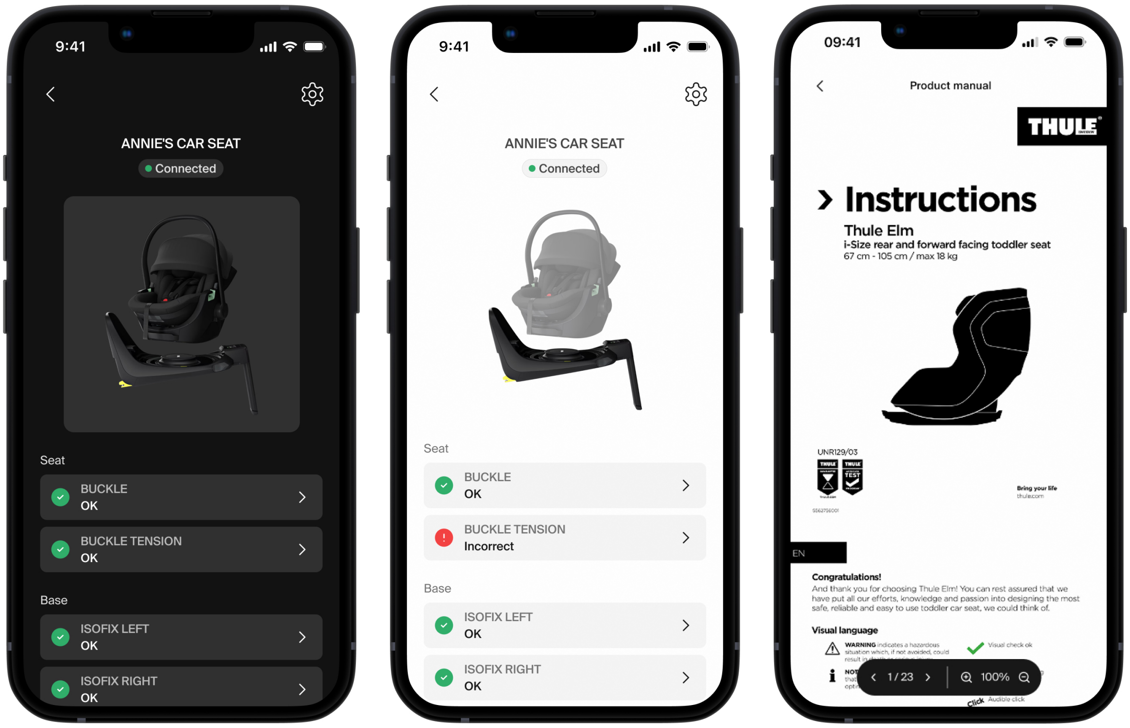

Figure 5.3: Proposed final design for the product page and the product manuals page of the Thule app. Available in both dark and light modes.

The Product Manual interface (Figure 5.3, right) received a considerable functional improvement. The initial PDF viewer depended only on pinch-to-zoom and scroll gesture, which necessitated two hands and fine motor coordination skills. To address this and meet WCAG 2.2 Success Criterion 2.5.1, the new PDF viewer was designed to include buttons for zooming and page navigation. Evaluation of the design verified that these dedicated controls provide useful one-handed accessibility, allowing users to navigate product manuals even when their other hand is occupied. Similar to the home page, the product page has also been updated to adapt to the system-wide dark mode.

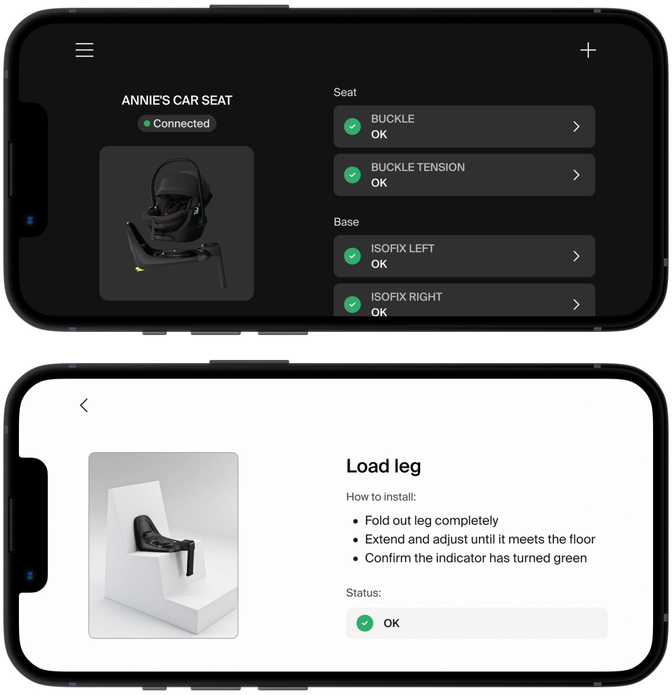

Figure 5.4: Proposed final design for the product page of the Thule app in landscape orientation. Available in both dark and light modes.

5.3.3 Settings Page

The settings page (Figure 5.5) was updated to incorporate newly developed features while maintaining the original information architecture. The layout now includes two new toggle options for Active Mode and Dark Mode. Furthermore, the settings page UI was updated to adapt to the system-wide dark mode.

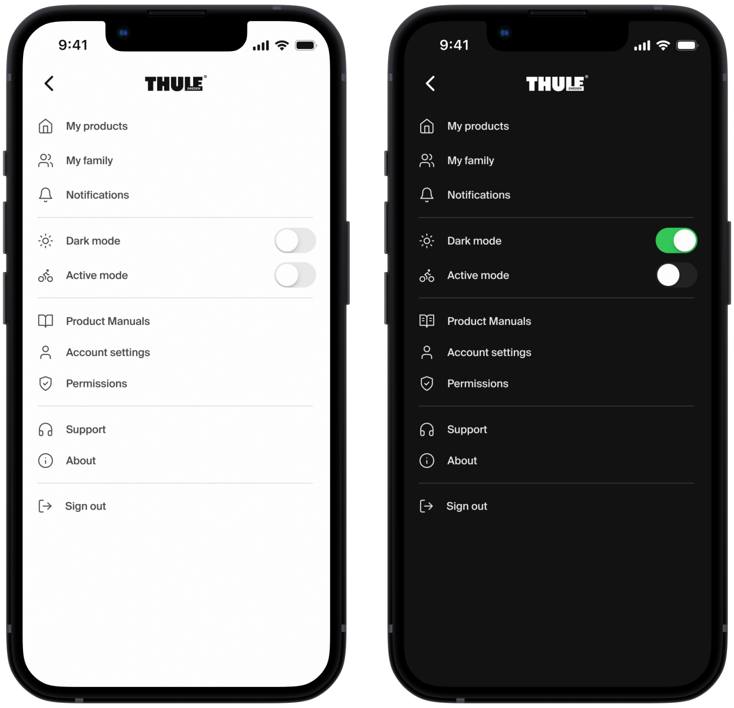

Figure 5.5: Proposed final design for the settings page of the Thule app. Available in both dark and light modes.

5.3.4 Active Mode: Product Page

The "Active Mode" is an optional interface toggle designed to improve usability in dynamic environments. The contextual inquiry done in Slottsskogen, strongly motivated the design of this feature. Active Mode serves as a specialized theme that intentionally prioritizes function over form. The interface aims to minimize the cognitive burden on the user by removing unnecessary visual features. This ensures that a user's divided attention is directed purely toward the necessary information for quick interactions.

To accommodate for the physical instability of dynamic environments, the Product Page's structural layout was redesigned as a grid-based, non-scrolling screen, shown in Figure 5.6. Eliminating vertical scrolling means that all key controls and information are always visible. This keeps critical alerts from being hidden below the fold when a user just has a short moment to look at their device. Furthermore, the typeface and iconography were dramatically scaled up to improve legibility from a distance. To compensate for lower dexterity, the interactive touch targets were extended much beyond the typical baseline. Following Fitts' Law, these huge buttons minimize the precision required to complete a task, reducing the likelihood of accidental inputs.

In contrast to the minimalist black & white aesthetic of the Thule app, the Active Mode utilizes orange as the primary color. This decision was made in order to visually separate the Active Mode from the regular theme of the app, while also giving it a consistent aesthetic within itself. Active Mode fully supports the system-wide light and dark modes. This ensures that the high-contrast layout can adapt to changing lighting conditions. The light mode version aims to reduce screen glare in direct sunshine, and the dark mode variation aims to eliminate ocular fatigue and blinding contrast when using the app in low-light conditions, such as parking at night.

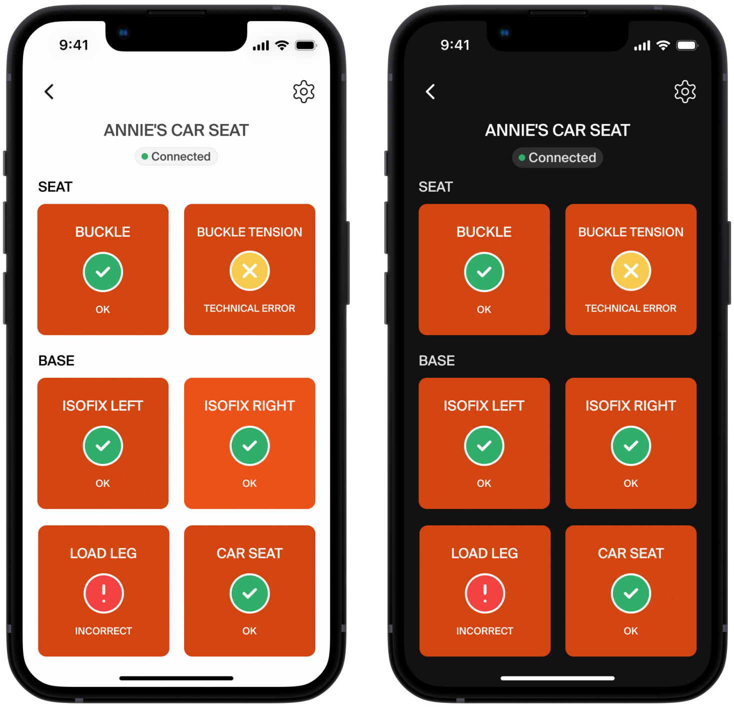

Figure 5.6: Proposed final design for the product page of the Thule app when Active Mode is turned on. Available in both dark and light modes.

5.3.5 Active Mode: Settings Page

As shown in Figure 5.7, the principles of the Active Mode are also applied to the settings page. When this mode is activated, the settings interface transitions to the simplified, high contrast visual language used on the product page, which includes larger buttons and scaled-up text for use on the go.

An important design choice for this page was to purposefully hide certain options while Active Mode was enabled. The motivation for this approach is to reduce visual clutter and provide the user with only the most relevant, high-priority options they may require while on the go. By deleting less commonly used options, the remaining controls can fit comfortably on a single, non-scrolling screen, even with significantly larger target sizes. If a user wants to access the entire list of options, they may easily turn off Active Mode at any time to return to the default, complete settings view.

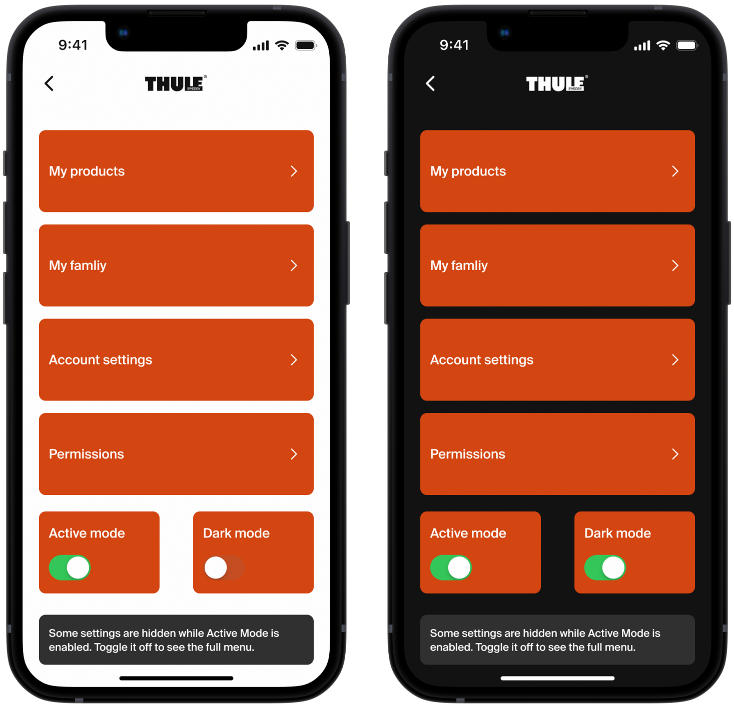

Figure 5.7: Proposed final design for the settings page of the Thule app when Active Mode is turned on. Available in both dark and light modes.

5.4 Recommendations for Creating App-Specific Recommendations

The development of context-specific recommendations, although intended for dynamic environments in this research, provides a universal basis. The insights acquired from this RtD process extend beyond the given context, resulting in adaptable recommendations for any digital product. By considering this short set of recommendations, design teams in any industry can create and test unique recommendations adapted to their specific user context.

Establish a Technical Baseline First

When developing specific rules for any digital product, laying a solid technical foundation with standard frameworks like as WCAG is an important first step. While these frameworks are effective for detecting core code parsing and static visual obstacles, they may neglect nuances of certain situational contexts. Treating broad standards as a starting point rather than a comprehensive solution enables designers to ensure basic accessibility compliance before delving into the unique friction points of their specific product environment.

Observe Users in the Wild

Although digital surveys give valuable broad data, they frequently fail to capture the complex, lived reality of actual product usage. It is recommended to do a contextual inquiry and watch your target demographic in their natural environment, whether that is a public park, a busy hospital or their living room. This qualitative approach enables researchers to move beyond static assumptions and find underlying constraints. Grounding recommendations in observed behaviors guarantees that the design requirements are based on real-world limitations rather than idealized scenarios.

Iterate Through Tangible Artifacts The development of custom recommendations should not only be a theoretical process. A continuous cycle of high-fidelity prototyping acts as an active method of inquiry. Teams can generate and refine interfaces to turn abstract survey data and field observations into testable design solutions. Prototyping acts as a filter to validate whether proposed recommendations actually resolve the identified pain points without introducing new friction. This ongoing cycle of development and refinement guarantees that the final recommendations are practical, proven, and ready for immediate implementation.

Test Under Realistic Constraints

Traditional usability testing in a laboratory setting is often insufficient for evaluating apps intended for the real-world. Evaluations must be conducted under simulated contextual conditions, requiring participants to face the actual stressors such as physical load, divided attention, or harsh lighting, that they will encounter while using the product. Forcing users to interact with the design under these simulated conditions ensures high ecological validity. This approach is crucial for revealing important ergonomic or cognitive problems that might otherwise go undiscovered.

6

Discussion

This chapter discusses the research findings and contextualizes the specific design efforts within the broader academic literature on mobile accessibility. It explicitly addresses the research questions, examines the methodology, discusses the study's shortcomings, and suggests future directions.

6.1 Answering the Research Questions and Interpreting Results

The first research question in this study aimed to identify the limitations of existing accessibility guidelines when applied in dynamic environments. The findings demonstrate that, while frameworks such as WCAG 2.2 provide an important technical baseline, strictly adhering to these static guidelines is insufficient for mobile applications designed for active, outside use. Because standard guidelines were mainly developed using readability concerns for static, indoor scenarios, they often fail to account for the unpredictable nature of mobile interaction.

Throughout the study, data collection techniques such as surveys, usability testing, and contextual inquiry repeatedly highlighted a common theme: users in dynamic environments encounter physical and environmental constraints that traditional guidelines do not sufficiently address. For example, excessive screen glare or the need to use a device with one hand create significant interaction challenges that standard contrast ratios and minimum target sizes do not fully address.

However, it is important to note that the broad nature of WCAG is both a strength and a weakness. After all, WCAG was developed to be universally applicable across all web and mobile platforms, which allows developers and designers to establish a reliable, standardized baseline for accessibility. Therefore, context-specific recommendations should not replace standard frameworks, rather, they should be applied after designers have achieved basic WCAG compliance. WCAG was designed to be universally applicable across all web and mobile platforms. This broadness enables developers and designers to establish a standardized baseline for accessibility. Context-specific recommendations should not replace standard frameworks, but rather be used after designers have achieved basic WCAG compliance. This layered approach enables teams to delve deeper into their target audience's specific, situational needs, which standard guidelines typically ignore.

The second research question explored how context-specific recommendations could be created and implemented to address these limitations. This question was answered not just using multiple data collection methods, but also using the RtD methodology, during which the act of designing generates new knowledge. This section divides the research question into two parts: formulation and application.

For the formulation stage, the research highlights the necessity of moving beyond assumptions and static data collection methods. Drawing directly on the practical experience gained throughout the RtD process, this research proposes a four-step framework (Establish Baseline, Observe in the Wild, Iterate Artifacts, Test Under Load) as a highly versatile blueprint for any designer looking to create context-specific recommendations for their product. This framework proposes that effective recommendations can only be designed by monitoring users in their natural settings, where they encounter true physical and cognitive friction, exposing the precise moments when static standards fall short in the real world.

For the application stage, the study resulted in a set of 14 context-specific recommendations, which were subsequently applied during the prototyping of the Thule mobile application. Instead of being restricted to a single feature of the app, the entire prototype demonstrates this applied method. For users who are physically constrained, basic ergonomic modifications to the standard interface, such as thumb-zone optimization and larger touch targets, offer an accessible foundation. In order to optimize cognitive clarity in dynamic situations, these principles also result in Active Mode, an optional interface theme that eliminates all unnecessary components and focuses on functionality. Overall, our findings show that accessibility in motion is largely dependent on ergonomic adaptation, functional minimalism, and high error tolerance. Where a user's physical surroundings demand their attention, usability of the application must take priority over aesthetic concerns.

6.2 Connection to Theory

The proposed designs and recommendations developed in this thesis are deeply intertwined with the academic theories introduced in Chapter 2.

Our findings are substantially consistent with SIID theory, which holds that environmental factors may impede a user as badly as a physical disability. The contextual inquiry revealed that parents pushing heavy strollers with one hand while using a mobile interface had a situational motor limitation functionally, which potentially emulated a permanent impairment.

The proposed design solutions created in this thesis are substantially shaped by the high-load reality of modern parenting, specifically addressing the situational motor limitations observed during the contextual inquiry of parents maneuvering strollers. The proposed interface reduces physical instability and poor dexterity caused by a parent having to maneuver a heavy stroller with one hand while carrying a child or operating hardware with the other by emphasizing the thumb-zone and greatly increasing touch targets. Furthermore, the introduction of a distraction-free Active Mode responds directly to the concept of technoference, offering a streamlined, utilitarian interface that allows for easy interactions. This emphasis on functional clarity over hedonic aesthetics enables parents to meet the Thule ecosystem's logistical demands, such as validating child seat safety, without diverting their attention away from their child or their physical surroundings. Finally, these parenting-centric features demonstrate the Curb-Cut Effect, in that a design that is strong enough to survive the stress of active parenting becomes more accessible to both the chronically impaired community and the overall user base.

6.3 Reflecting on Methodologies

The combination of RtD and the Double Diamond process model provided a strong structural foundation for this thesis. While RtD offered the generative philosophy that design is inherently a method of inquiry, the Double Diamond provided a strict structure that prevented premature solution-finding. By having Discover and Define phases, the methodology ensured that the project was founded on actual user data rather than theoretical assumptions.

This approach allowed the integration of various data collection methods. The initial general survey and the pilot-tester survey were critical in providing broad, quantitative baselines for user pain points. However, it was the qualitative methods, particularly contextual inquiry, that gave the most valuable insights. While surveys highlighted what users had trouble with, witnessing parents handling strollers in Slottskogen revealed why these problems arose. This qualitative context was critical for understanding the physical compromises users make, which effects how an interface should be designed.

The physical act of designing and producing the high-fidelity artifact in the Develop phase highlighted important ergonamics related information that surveys and static code audits ignore. Furthermore, it was critical to evaluate these prototypes utilizing the RITE method with simulated physical movement. For example, testing the prototype while walking revealed that pressing 24x24 pixel targets accurately is difficult while in motion, although it passes WCAG 2.2 guidelines. Finally, this context-driven designerly knowledge was only possible since the process required an iterative cycle of testing and constant refinement.

6.4 Limitations

Critical reflection is an important component of academic rigor because it ensures that the conclusions of every study are understood within the unique context and restrictions of its implementation. While this study used a multi-methodological approach to base the design process on actual user data, it is important to recognize the inherent limits that defined the breadth and depth of the research. Every study will have multiple limitations. The limitations deemed most important by the researchers are discussed further in this section.

6.4.1 General Survey

One limitation of the study phase was the exclusion of demographic questions from the general survey. The findings could not be segmented or identify how certain demographic characteristics affected mobile usage patterns since no data on participants' age, gender, or technical literacy was collected. The lack of a participant profile makes it difficult to detect potential biases in the sample or link survey findings with the target parental group's individual life phases and backgrounds.

6.4.2 Evaluation first Iteration

The assessment of the first iteration was carried out utilizing the RITE approach. While the participant pool was restricted to two people. The researchers acknowledge the small sample size as a constraint of the first evaluation phase. However, these sessions produced deep, qualitative designer knowledge that supplied the clarity required for refining. Despite the modest size of the original test group, the research maintained a solid evidential foundation by combining these detailed, situational insights with a wide empirical baseline. This decision was theoretically justified by the fact that small-scale testing is sometimes adequate to reveal major usability issues and give design insights.

6.4.3 Contextual Inquiry

One disadvantage of the contextual inquiry was the small sample size of only four people. While these concentrated sessions gave rich, qualitative insights into the lived experience of mobile usage on the go in Slottsskogen with a stroller, the limited sample size restricts the findings' generalizability to the larger parental community. Furthermore, because the study was conducted in the unique environmental context of a public park, the findings may not completely account for the different stresses or physical constraints faced in different urban environments. As a result, these findings should be seen as situational qualitative insights that guided the design process, rather than a complete depiction of all conceivable mobile parenting scenarios.

6.4.4 The Ethical Risk of Accessibility Without Disability

Designing for Situationally Induced Impairments and Disabilities (SIIDs) without primary involvement and major input from the disabled community creates a profound ethical tension and a core research limitation. While this study emphasizes the importance of the Curb-Cut Effect, a significant concern remains that an overemphasis on situational demands may compromise the unique needs of people with permanent disabilities in favor of the interests of the non-disabled majority.

Although many design solutions, such as high-contrast modes and target-size optimization, are fundamentally based on long-standing advocacy for people with permanent impairments, when an interaction design project utilizes these principles primarily to smooth out the usability issues for able-bodied individuals, it introduces the risk of separating the design solution from the political struggle that gave rise to it. Target-size amplification, high contrast states, and gesture alternatives are examples of important accessibility features rather than just being visual patterns optimized for corporate design systems.

By applying these accessibility aspects primarily to a premium parenting and leisure lifestyle ecosystem, this study walks a thin ethical line. Human-computer interaction research runs the risk of unintentionally softening the reality of impairments by repackaging accessibility under the highly marketable label of situational convenience. The risk that follows is that industry stakeholders may view accessibility as beneficial only when it serves the "productive", non-disabled consumer baseline. This could reinforce a paradigm in which the long-term needs of marginalized users are pushed to later iterations as an economically secondary concern.

A similar limitation exists in the specific approach that this study applies to the WCAG 2.2. While alternative models and theories like Ability-Based Design, Inclusive Design Principles, or Critical Disability Studies offer different perspectives, this thesis focused on WCAG 2.2 due to its status as the primary compliance metric for industry standards. Prioritizing this structured, checklist-based tool allowed us to guarantee basic functional correctness for situational challenges. Additionally, we apply the WCAG 2.2 guidelines largely to address SIIDs, which shows a limitation in our scope because it may not adequately account for the complex and diverse demands of people with permanent disabilities. As a result, while WCAG 2.2 assures that our design is functionally accessible, we acknowledge that utilizing it only to reduce situational challenges is a methodological limitation that future work must address through more direct involvement with the disabled population.

To bridge this gap, a deeper ethical distinction must be established between a situational impairment and a chronic, permanent disability. A parent operating a stroller while using an interface is temporarily limited in their ability to move and concentrate, however, they have the freedom to stop what they are doing, change their immediate physical surroundings, or postpone the digital connection completely. This escape strategy is entirely absent for a user who has a permanent physiological or visual disability. Resolving a situational inconvenience like improving legibility under screen glare could overlap with a standard accessibility requirement, but it is not equivalent to creating an experience that respects the complex, systemic ways in which permanently disabled users navigate digital interfaces. Active Mode should therefore be clearly recognized as a particular type of context-aware performance optimization that serves as an ergonomic aid in dynamic environments, rather than a broad claim to universal inclusivity.

This theoretical boundary was further solidified by practical recruitment hurdles faced during the discovery phase. The research team made multiple attempts to collaborate with Synskadades Riksförbund (the Swedish Association of the Visually Impaired) in order to recruit volunteers and obtain knowledge about their experience. Unfortunately, the research team never heard back from the organization despite numerous contact attempts. Due to this lack of communication and the project's strict schedule restrictions, it was impossible to carry out a thorough investigation into how the app design meets the needs of the visually impaired community.

In the field of disability research, marginalized advocacy groups are frequently approached by academic teams working during short university semesters. These short-term projects may unintentionally develop extractive research practices, in which groups are requested to quickly deploy their limited resources, recruit volunteers, and give qualitative labor to validate student designs or business prototypes. Viewed through this critical perspective, the organization's lack of communication should not be classified solely as an administrative failure or a passive research barrier. Instead, it could be interpreted as a sign of research fatigue and a systematic conflict within traditional academic approaches.

This project succeeded in managing to conclude within its tight time constraints by completely shifting its focus to SIIDs, but it draws attention to a potential systemic weakness in typical design sprints, which is the continued use of able-bodied proxies to model or simulate physical limitations without establishing genuine, long-term connections with permanent self-advocacy institutions.

As a result, the exclusion of participants with permanent visual disabilities shifted from an initial recruitment goal to a deliberate scoping boundary for this project. Proceeding with the evaluation under these parameters carries the distinct risk of prioritizing the preferences of the non-disabled majority over the non-negotiable requirements of permanently impaired users, potentially validating designs that address situational inconvenience while overlooking deeper systemic barriers. The research team accepted this risk due to strict project timeline constraints, shifting the analytical focus entirely toward SIIDs. Ultimately, acknowledging this exclusion is vital for maintaining critical objectivity. It explicitly defines the boundaries of our usability claims and ensures that the resulting Active Mode is framed not as a comprehensive universal design solution, but as a specialized, context-driven exploration that must be validated by the permanently disabled community in future research.

6.4.5 Thule Mobile App Proposed Final Design

It is critical to underline that the final design described in this thesis, particularly the Active Mode, should be seen solely as a proposed solution. While the first iteration of the prototype underwent qualitative usability testing to validate improvements, the second iteration which included Active Mode was not tested with human participants. The data from the contextual inquiry and the focused survey of pilot testers served as the foundation for this secondary design exploration, although its success is still undetermined. Active Mode marks a tactical shift in which function takes precedence over form, with a grid-based, non-scrolling architecture and high-contrast orange signifiers to facilitate interactions. However, because this solution was not empirically tested, we cannot say if removing product graphics or using full-frame status colors lessens cognitive strain or introduces new navigation hurdles. The proposed Active Mode thus serves as a generative artifact, demonstrating a potential "preferred state" for future development instead of being a final, validated design.

6.5 Ethical Considerations

Design is never neutral [80]. Every interface decision implicitly prioritizes certain users while marginalizing others. This thesis explores and proposes a context-specific guideline and an artifact as a redesign of the Thule app. This chapter outlines the beneficiaries of this research, analyzes the dynamics of inclusion and exclusion, and clarifies the ethical use of technology in the study. It also serves as an insight into the thought-process behind the different decisions made during the thesis.

6.5.1 Target Audience and Beneficiaries

The primary demographic for this study includes people on-the-go, specifically users who manage physical hardware in dynamic environments. This group frequently includes individuals engaging in activity with children, pets, or multitasking, whose attention is divided. However, from an ethical standpoint, the work considers a more vulnerable subset of this group: users suffering from SIIDs such as SVI. For instance, this includes individuals operating in suboptimal light conditions where screen glare can cause temporary visual impairments, or those with varying degrees of light sensitivity. By considering these extreme use cases, the design adheres to the "Curb-Cut Effect" [15], an example of Universal Design, which is the principle that features designed for the marginalized inevitably benefit the majority [80]. We recognize the ethical criticism within the disability community that the Curb-Cut Effect can occasionally co-opt disability issues to serve the interests of the non-disabled majority, it still offers a compelling practical argument for universal design. While situational impairments are our main emphasis, we acknowledge that the design solutions we suggest stem from the long-standing advocacy of people with permanent disabilities. Therefore, the objective is to make sure that the demands of the most vulnerable users continue to be the major design power rather than a secondary benefit, as opposed to sanitizing disability for a general market. In this context, reducing visual distraction is not just a convenience. It is a safety imperative for users who must remain aware of their physical surroundings.

6.5.2 Dynamics of Inclusion and Exclusion

By only relying on a standard white background and black text, the current design choices may be suboptimal for users in dark environments or those with visual fatigue or simply those who wish there were more visual options. Since the application is still in active development, we believe there needs to be more detailed accessibility recommendations that should be considered, which in the end will benefit the target demographic.

Another aspect to consider is that while this study makes context-specific recommendations to reduce environmental stresses, a thorough assessment of digital inclusion demands a refined approach and understanding that takes into consideration both cognitive differences and social inequalities.

In terms of cognitive accessibility, using a mobile interface in a dynamic outside setting naturally causes high sensory stimulation and split attention, and therefore may result in cognitive overload. An individual's capacity to comprehend information is firmly connected to their past knowledge, generating major individual variances in how successfully they can traverse a particular system under stress [81]. The concept of Active Mode can directly address this issue by employing functional minimalism to reduce unnecessary cognitive burden [82]. By removing unnecessary branding images, reducing visual hierarchies, and displaying clear options, the system may reduce the mental processing thresholds required for interaction, responding to individual variances in cognitive limits and processing restrictions [81][82].

Simultaneously, the implementation of a Smart Product-Service System (S-PSS) raises socioeconomic concerns that pose a specific danger of digital exclusion [83]. Because the application's continuous feedback loop is fundamentally reliant on high-end physical equipment, such as air filtration covers or sensor-integrated vehicle seats and smartphone technology, safety-critical technologies could become linked to economic privilege. This paradigm threatens to commodify structural security, essentially tying proactive safety measures to a monetary premium. In the wider conversation around the digital divide, genuine social inclusion relies on addressing how technology interacts with deep-seated socioeconomic systems and institutional disparities, rather than simply providing hardware access [83].

6.5.3 Societal Impact: Advantages and Disadvantages

Advantages: This thesis aims to directly improve the Thule application through the development of accessibility recommendations and a high-fidelity Figma prototype for the application. However, the potential societal impact of this thesis is not limited to Thule. Broad adoption of these context-aware principles would significantly advantage anyone using mobile screens in a dynamic environment. It is therefore possible that the study will go beyond brand-specific applications because these concepts contribute to the broader discussion about Active Safety in mobile HCI.

Disadvantages: There's a possibility that Thule does not find this work meaningful for their company and chooses not to incorporate the findings into their product. The possibility of "fragmented implementation", in which Thule adopts certain components without committing to the underlying S-PSS logic, presents an ethical dilemma. Another potential disadvantage is that this study mainly focuses on SIIDs and not permanant impairments. Incorporation of the developed recommendations needs to be done with consideration to make sure they cover the vast majority of users and adhere to the Universal Design philosophy.

6.5.4 Technology & AI Ethics

This research relies on standard industry prototyping tools, specifically Figma, to visualize and test the proposed interventions, as well as TestFlight to access the development version of the app.

6.5.4.1 AI Ethics

While the emergence of AI ethical frameworks suggests a dedication to responsible innovation, Munn [84] contends that they ironically support the status quo. In theory, these principles promote great ideals. Nevertheless, in fact, they are meaningless due to ambiguity, isolated from industrial realities, and toothless due to a lack of enforcement. Consequently, this leads to "ethics washing", where firms employ voluntary rules to preempt binding regulation while conducting business as usual [84]. So what does this mean?

In contrast, Radanliev [85] claims that AI ethics are becoming more operationalized through rigorous technical and regulatory integration. Far from being toothless, many frameworks are growing into legal requirements, such as the EU AI Act [86], which imposes financial penalties of up to 4% of a company's global revenue for noncompliance. This study reveals how ethical ideals such as transparency and fairness are converted into practical industry tools such as fairness-aware algorithms and routine audits, which have a direct impact on system design. Instead of supporting ethics washing, a strong ethical lifecycle is presented as a requirement for safe, sustainable, and socially good innovation. We take a balanced stand, carefully considering different angles.

6.5.4.2 The Role of AI:

Artificial Intelligence will be employed in this study strictly for auxiliary tasks, such as synthesizing thematic trends from interview notes, generating dummy content for high-fidelity prototypes, and improving the grammar of a given text. AI will not be used to simulate user testing or replace human participants at any given stage during the thesis. Nor will AI be used for decision-making.

We have made the deliberate ethical choice to avoid AI from simulating user testing or taking the place of human subjects. AI is capable of processing data, but it lacks phenomenological consciousness, which is for example the lived experience of navigating a busy urban environment while fumbling with an interface. We guarantee that human empathy and moral responsibility continue to be the fundamental forces behind the design process by limiting AI to auxiliary activities. In order to ensure that the connected mobility of the future stays human-centric, this project simply represents a study carried out by humans, for humans.

6.6 Future Work

This thesis is a humble step toward redefining mobile accessibility by emphasizing the friction generated by dynamic settings and situational impairments. While the created standards and the Active Mode prototype may solve immediate usability issues, the shift from a research artifact to a fully inclusive digital ecosystem necessitates additional research into the human experience. Future research should go beyond technical validation of interface elements to investigate how these technologies fit into users' complex, often fragmented, everyday lives.

The human element of technoference and the cognitive dissonance parents experience when using mobile devices also merit more investigation. While this study attempted to lessen cognitive burden using a simpler Active Mode, future research could look into how such interfaces affect the quality of face-to-face interactions between parents and children. Subsequent research should use longitudinal approaches to evaluate how people adjust to these instructions over time, rather than just one session. This would tell whether the streamlined, high-contrast layouts continue to deliver value after the "novelty" goes off.

The current study only covers a portion of user needs, but offering important insights regarding mobile app accessibility in dynamic settings and situational impairments, such as utilizing an interface while walking or in high-glare environments. Testing and improving these design principles for people with permanent impairments is an important area for future research.

Although the current design concentrates on manual and visual interactions in motion, future research should investigate deep integration with specialized assistive technologies (such as VoiceOver, TalkBack, and external switch devices) to make sure that the app's dynamic features don't create obstacles for people who use non-traditional input methods.

By bridging the gap between momentary convenience and permanent accessibility, future research can develop these recommendations into a truly inclusive framework that supports the broadest range of human ability.

Additionally, future research should look beyond compliance-driven metrics to explore how alternative accessibility models can be integrated into the design system. While this thesis relied on the structured guidelines of WCAG 2.2 to establish technical mobile standards, upcoming iterations would benefit from exploring more holistic models such as Ability-Based Design, Inclusive Design Principles, or Critical Disability Studies. Investigating these models will allow future researchers to shift from a mindset of basic checklist compliance toward a more comprehensive, strength-based approach to accessability.

The most immediate and crucial next step for this research is to close the evaluation gap caused by the project's time constraints. While the first iteration of the Thule mobile application underwent qualitative usability testing, the second iteration, which introduced the specialized Active Mode and significant structural departures from the original design system, remains a proposed artifact that has yet to be tested by humans. As a result, future research must prioritize a full summative evaluation of this second iteration in order to empirically evaluate the efficacy of the applied adjustments.

Finally, the geographical and demographic scope of this study could be expanded to improve the generalizability of the findings. Future researchers can determine how different life stages affect mobile usage habits in motion by gathering demographic data such as age, gender, and technical backgrounds. Finally, the goal is to translate these context-specific insights into a living framework that supports the whole range of human potential and is human-centric and truly inclusive.

7
Conclusion

This thesis, conducted in collaboration with Thule Sweden AB, was driven by the desire to bridge the gap between static digital accessibility guidelines and the fluid, unpredictable reality of mobile use in motion. As mobile phones have evolved into important hubs for managing physical products, this study looked into how designers could design more resilient interfaces for active use-case scenarios.

By addressing the limits of existing accessibility frameworks, this study demonstrated that standard guidelines, such as WCAG 2.2, provide a necessary technical foundation but are unsuitable for dynamic environments. Because these guidelines were primarily established for static, indoor contexts, they typically fail to account for situationally induced impairments and disabilities (SIIDs). The data acquired through surveys, usability testing, and contextual inquiry repeatedly revealed that conditions, such as extreme screen glare or the need for one-handed operation, generate significant interaction barriers that core principles cannot fully address. As a result, the study proposes for a layered approach, in which context-specific recommendations are implemented on top of fundamental WCAG compliance to overcome these practical limits.

To explore how these specialized recommendations could be developed, the study used the RtD methodology. Moving beyond theoretical assumptions and static surveys, the study combined practical experience into a four-step framework: establish baseline, observe in the wild, iterate artifacts, and test under load. This blueprint shows that effective accessibility rules necessitate observing users in their real environments.

14 context-specific recommendations and a high-fidelity prototype of the Thule mobile application were generated as final artifacts of the thesis. Fundamental ergonomic changes, such as larger touch targets and thumb-zone optimization, give a solid foundation for physically constrained users. These principles resulted in the Active Mode interface variation, which removes unnecessary visual components with an aim to improve cognitive clarity and tolerance for errors. The redesign highlights that when a user's attention is called upon by exterior physical factors, utilitarian usability must take precedence over traditional hedonic design.

In conclusion, this thesis presents both a methodological roadmap and practical design solutions. By emphasizing the lived reality of active users, it emphasizes that true digital accessibility necessitates interfaces that are as adaptive and resilient as the people using them.

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A

Project Plan

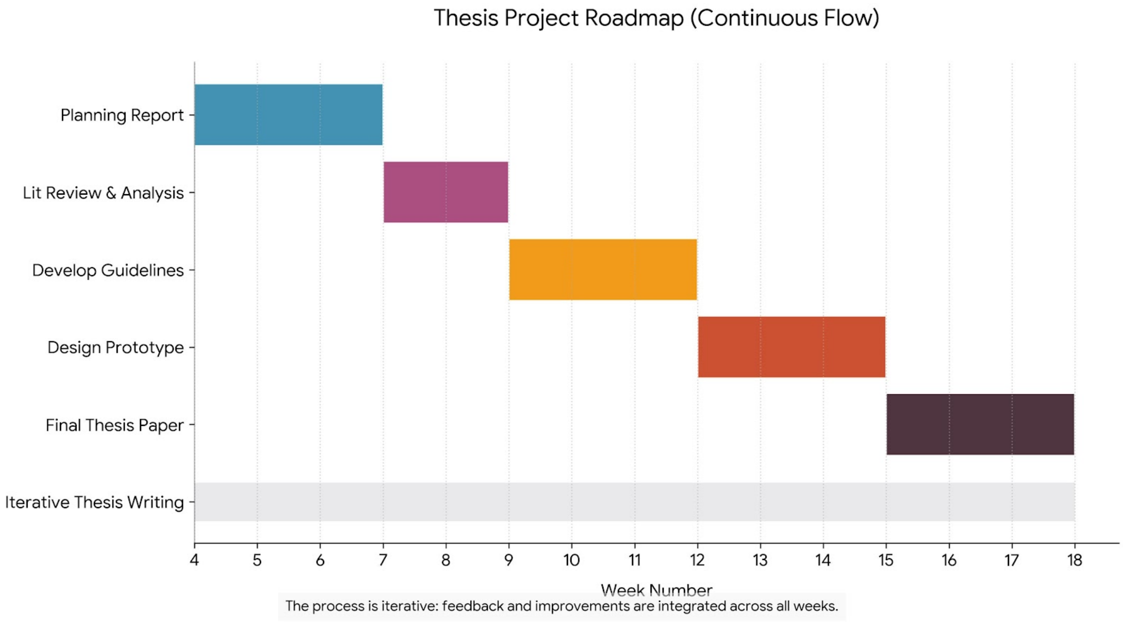

Figure A.1: Gantt chart of the estimated time plan.

B

General Survey: Mobile Accessibility in Dynamic Environments

Administration Context: This survey was conducted as a primary data collection instrument between 2026-02-10 and 2026-02-24. It was distributed digitally via Google Forms to a general audience, through social media and a cold e-mails. The sample size in the end was made up of 65 participants.

Informed Consent and Privacy

Before commencing the survey, all participants were informed about the scope of the study and the intended use of the data for academic research. Participation was voluntary and anonymous, with data handled in compliance with general research ethics regarding confidentiality.

Survey Blocks and Categorization

The survey is divided into four thematic blocks designed to map user behavior, perceived difficulty, physical constraints, and subjective industry evaluation.

Block 1: Usage Context and Exposure

This section establishes the frequency and environmental settings of mobile use in motion.

Q1. Which of the following dynamic environments do you most frequently use your mobile phone in?
Type: Multiple Selection (with open-ended option)
Options: Walking/Strolling Outdoors; Commuting (e.g., bus, train, metro, tram); In a moving car as a passenger; Driving a vehicle; Riding a bike; Exercising/Running; In a public outdoor space (e.g., park bench); Other.

Q2. On average, how often do you use your mobile phone in dynamic (moving or rapidly changing) environments per week?

Type: Frequency Scale
Options: Frequently (10+ times); Moderately (5-9 times); Occasionally (2-4 times); Rarely (1 time or less).

Block 2: Comparative Usability and Friction

Quantitative assessment of the difficulty gap between static and dynamic interaction.

Q3. How would you rate the overall difficulty of using mobile apps while in motion or in dynamic environments in comparison to static environments (e.g., sitting in your room)?
Type: 5-point Likert Scale (1: Not at all difficult 5: Extremely difficult)

Q4. How often do you experience the following difficulties when using your phone in dynamic environments?
Type: Matrix Grid (Scale: Never, Rarely, Sometimes, Often, Always)

- Difficulty seeing the screen due to sunlight/glare
- Difficulty tapping/interacting accurately due to movement/shaking
- Difficulty hearing audio alerts/content due to background noise
- Distraction or cognitive overload (paying attention to surroundings)
- Physical encumbrance (e.g., holding bags, one-handed use)
- Difficulty reading small text or seeing small targets
- Issues with automatic screen brightness/color adjustment

Block 3: Qualitative Experience and Interaction Constraints

Mapping specific physical barriers and content types that hinder accessibility.

Q5. Thinking about the last time you struggled to use a mobile app in a dynamic environment, briefly describe the situation and the app you were using.
Type: Qualitative/Open-ended (Optional)

Q6. Which physical interactions are most challenging for you in dynamic environments?
Type: Multiple Selection
Options: Typing/Text Input; Tapping small buttons; Swiping/Gestures; Viewing the screen due to glare or movement; Holding the device securely.

Q7. Which type of content interaction is most difficult for you in dynamic environments?
Type: Multiple Selection
Options: Reading long articles/messages; Typing/Inputting text; Navigating menus/buttons; Using map/navigation features; Watching videos/Media consumption.

Block 4: Subjective Industry Evaluation

Capturing the user's perception of current development standards.

Q8. To what extent do you agree with the statement: "Mobile app developers sufficiently consider accessibility for users in dynamic environments."
Type: 5-point Agreement Scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree)

C

Prototyping - Iteration 1

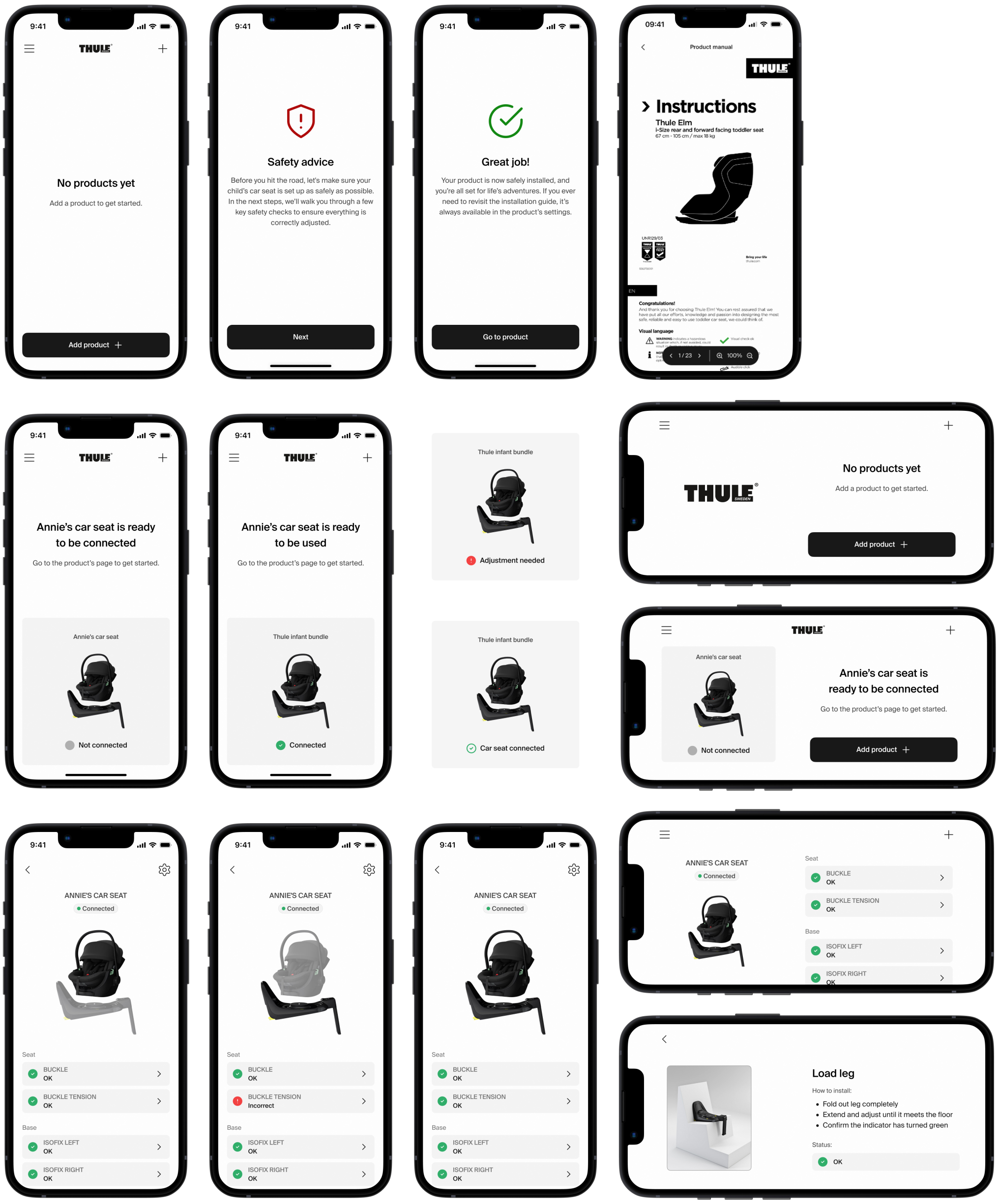

Figure C.1: Light mode designs from the prototyping iteration 1

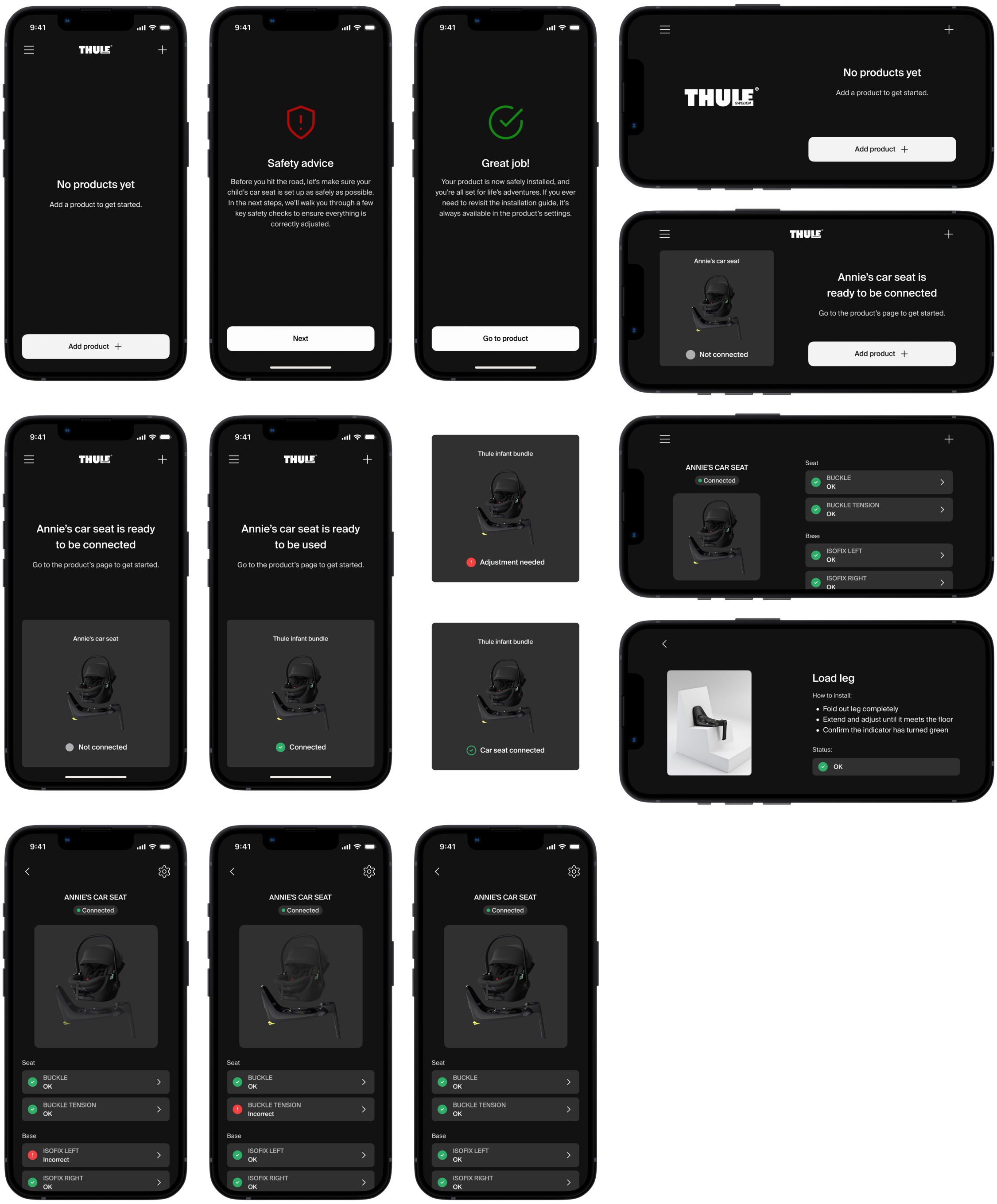

Figure C.2: Dark mode designs from the prototyping iteration 1

D

Semi-structured interviews

Semi-Structured Interview Guide

Informed Consent and Privacy

Before starting the interviews, the two participants were informed about the scope of the study and the intended use of the data for academic research. Participation was voluntary and anonymous, with data handled in compliance with general research ethics regarding confidentiality.

The following questions provided the framework for the semi-structured interviews conducted post-testing. In line with the flexible nature of this method, the researcher used these as a baseline to explore specific participant behaviors observed during the RITE sessions.

1. How did the placement of the 'Add Product' and navigation buttons feel when you were using the app with one hand?
2. How would you describe the ease of tapping the navigation icons while you were simulating movement (or walking)?
3. How does the navigation bar look? Do the icons look too small, too big, normal? Is there anything that catches your attention?
4. You used the new zoom and navigation buttons in the manual viewer; how did that compare to your usual experience of 'pinching' to zoom on a phone?
5. In what situation do you think you would prefer the buttons over standard gestures?
6. If you were using this app in bright sunlight or at night, how do you think light and dark mode would affect your ability to read the information?
7. Now that you have tried the app in a low-light environment, what are your thoughts on light vs. dark mode?
8. What are your thoughts on the landscape mode of the app?
9. Does the interface feel like a premium Thule product to you? Why or why not?

Summarized Interview Notes

The following table provides a summary of the observational notes and participant feedback collected during the semi-structured interviews.

Focus Area	**Summarized Interview Notes**
One-Handed Ergonomics	Bottom-aligned 'Add Product' button prevents thumb strain and is effective for smaller hands. Top navigation causes a 'grip adjustment' but is accepted as a design convention.
Mobility and Accuracy	Negative space around icons successfully prevents accidental triggers while walking. The layout provides high error tolerance during active movement.
Navigation Aesthetics	The navigation bar functions as 'invisible UI' with low cognitive load, meeting the standard mental model for mobile interfaces.
Manual Viewer Controls	Pinch gestures remain favored for precision, while dedicated buttons are viewed as a significant one-handed accessibility feature for rapid consumption.
Lighting and Legibility	Light mode is perceived as effective for high-glare/sunlight. Dark mode is preferred for low-light environments to prevent ocular fatigue.
Landscape Orientation	The mode feels 'premium' and 'website-like,' though there is uncertainty regarding the specific real-world context for its use.
Brand Perception	Minimalism and functional simplicity align with Thule's premium identity. Participants cautioned against 'over-design' to avoid a tacky aesthetic.

Table D.1: Summary of qualitative participant feedback.

E

Contextual Inquiry

This appendix contains the raw observations and interview summaries from the contextual inquiry conducted at Slottsskogen Park. The study involved four participants using strollers in the park.

Participant 1: Mother

Context: Walking on asphalt and gravel paths with a six-year-old child. High multitasking requirement.

Observations

- Participants walking speed slowed down noticeably when the mobile phone was retrieved from her pocket.
- There have been instances where the participant lost control of the stroller while steering it with one hand and using the phone with the other hand.

Key Interview Insights

- The participant performs quick tasks such as changing songs or checking notifications while in motion, but stated, "I definitely stop moving altogether if I need to do anything that requires more complex interaction".
- Steering a heavy stroller with one hand is harsh on her wrist and arm, making extended phone use uncomfortable.
- Movement and bumpy terrain make hitting small targets difficult. The participant stated, "It is very annoying to have to tap three times just to close a pop-up".

Participant 2: Father

Context: Pushing a double stroller uphill while managing a walking toddler.

Observations

- The participant had to support the handlebars with his elbow to free up his right hand for phone interaction.

- Visible frustration was observed.
- The phone was stowed in the bottom basket after the interaction.

Key Interview Insights

- The participant noted that controls at the top of the screen are unreachable while maintaining a grip: "I can't reach that with my thumb while my elbow is supporting the handle".
- He mentioned, "The physical effort of the climb takes up most of my focus. I don't have the mental energy to decode a complex notification".
- Expressed a strong preference for buttons in the thumb-zone (the bottom of the screen) to avoid shifting his grip.

Participant 3: Mother

Context: Bright sunlight with grocery bags hanging from the stroller handle. High frequency of interruptions from her child.

Observations

- Usage was characterized by very short glances at her phone.
- The participant frequently stopped using her phone to interact with her child.

Key Interview Insights

- The participant stated, "The glare off the screen is so bad today that it basically turns into a mirror".
- Frustration was expressed regarding apps that reset upon locking. The user needs the app to "stay exactly where I left it".
- Taking hands off the bar felt dangerous due to the risk of the stroller tipping backward from the weight of the bags.

Participant 4: Mother

Context: Quiet wooded area with a sleeping infant. Phone mounted to the handlebars via a plastic clip.

Observations

- The participant walked with caution and covered the phone screen with her hand when notifications lit up to protect the infant's sleep.
- Mobile phone usage was performed very slowly and deliberately.

Key Interview Insights

- Haptic feedback was disabled because she was worried about the buzzes waking up her infant.
- The user stated that she uses a dark mode, especially for "nap walks" because regular themes become too bright in dark, shaded areas. The aesthetic was also appreciated.
- As the user was already wearing earbuds, she expressed that voice status updates, such as Siri, but in-app, would be very nice to avoid looking at the screen.

F

Targeted Survey: Hardware-Software Integration for Pilot Testers

Administration Context: This survey was conducted between 2026-04-23 and 2026-04-30. It was distributed via a dedicated group chat to a purposive sample of pilot testers involved in the field-testing of Thules back sensor and child safety seat prototypes. The survey remained open for one week, resulting in a total of 16 completed responses.

Informed Consent and Privacy

Participants were required to confirm their consent before accessing the questionnaire. The instructions specified that participation was voluntary, anonymous, and that data would be used exclusively for evaluating the Thule mobile applications usability in real-world, dynamic conditions.

Q1. When using the [Parking Sensor / Car Seat] product screens in a dynamic environment (e.g., while standing outside the car, holding a child, or moving around the vehicle), I can comfortably reach and interact with the interface. *Type: 5-point Likert Scale*

Q2. The [Parking Sensor display / Car Seat safety status indicators] remain clearly readable in challenging lighting conditions (e.g., bright sunlight, dim parking garages, or nighttime).
Type: 5-point Likert Scale

Q3. When I need to act quickly (e.g., checking sensor clearance while reversing, or verifying my child's seat is correctly installed), the most critical information is immediately visible without scrolling.
Type: 5-point Likert Scale

Q4. When something shows an error or warning (e.g., a Parking Sensor alert or a red indicator on the Car Seat safety checklist), I clearly understand what is wrong and what steps to take to fix it.
Type: 5-point Likert Scale

Q5. The initial setup process (scanning the QR code, pairing the device, and following the installation guide) was straightforward and easy to complete without external help. *Type: 5-point Likert Scale*

Q6. When my phone is mounted in a fixed position (e.g., a car cradle or stroller handle), the app's layout adapts well and all important information remains accessible without needing to unmount the device.
Type: 5-point Likert Scale

Q7. The personalization features (e.g., naming my product, choosing a child avatar, or selecting alert presets) make the app feel tailored to my personal needs.
Type: 5-point Likert Scale